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THE Codorus Creek WASTEWATER MANAGEMENT STUDY

APPENDIX A – TECHNICAL STUDIES – VOLUME III

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THE Codorus Creek WASTEWATER MANAGEMENT STUDY.

APPENDIX A. TECHNICAL STUDIES, VOLUME III.

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CODORUS CREEK

WASTEWATER MANAGEMENT STUDIES

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I. INTRODUCTION

Scope of Report

This report investigates wastewater management alternatives for municipal and industrial discharges to the Codorus Creek sub-basin of the larger Susquehanna River Basin. Treatment technology choices, alternative levels of performance and various systems configurations are evaluated for cost and performance relationships relative to present and long-range water quality management objectives.

Technology choices evaluated include land treatment as an alternative to water process based-advanced waste treatment.

Performance alternatives considered range from only secondary treatment with phosphorus reduction linked to out-of-basin discharge to the highest level of organic and nutrient removal available with present technology. Treatment system configuration alternatives evaluated range from complete centralization to a continuation of the present pattern of localized development.

Specific water quality management considerations reflected in technology and performance evaluation include reduction in the discharge of the eutrophication nutrients (phosphorus, ammonia, nitrogen and total nitrogen), maintenance of adequate dissolved oxygen, control levels of viral and bacteriologic pathogens, effects on recreational activities and public water supplies, control of toxic substances, consistent reliability of performance, thermal effects and aesthetic quality conditions (color and turbidity).

Broader water resources management considerations reflected in the formulation and evaluation of alternatives include reuse of treated wastewater for conservation of available water supplies and maintenance or enhancement of stream flow consistent with desired land and water development objectives.

Relationship to Other Reports

This report is the third in a series of project reports in the development of the Codorus Creek Wastewater Management Plan. The first two reports, designated Phase I and Phase II, deal in detail with existing conditions and long-range future requirements, respectively. These reports provide the analysis basis for the problem definition, flow projections and water resources management relationships reflected in this report.

Regional Study Area

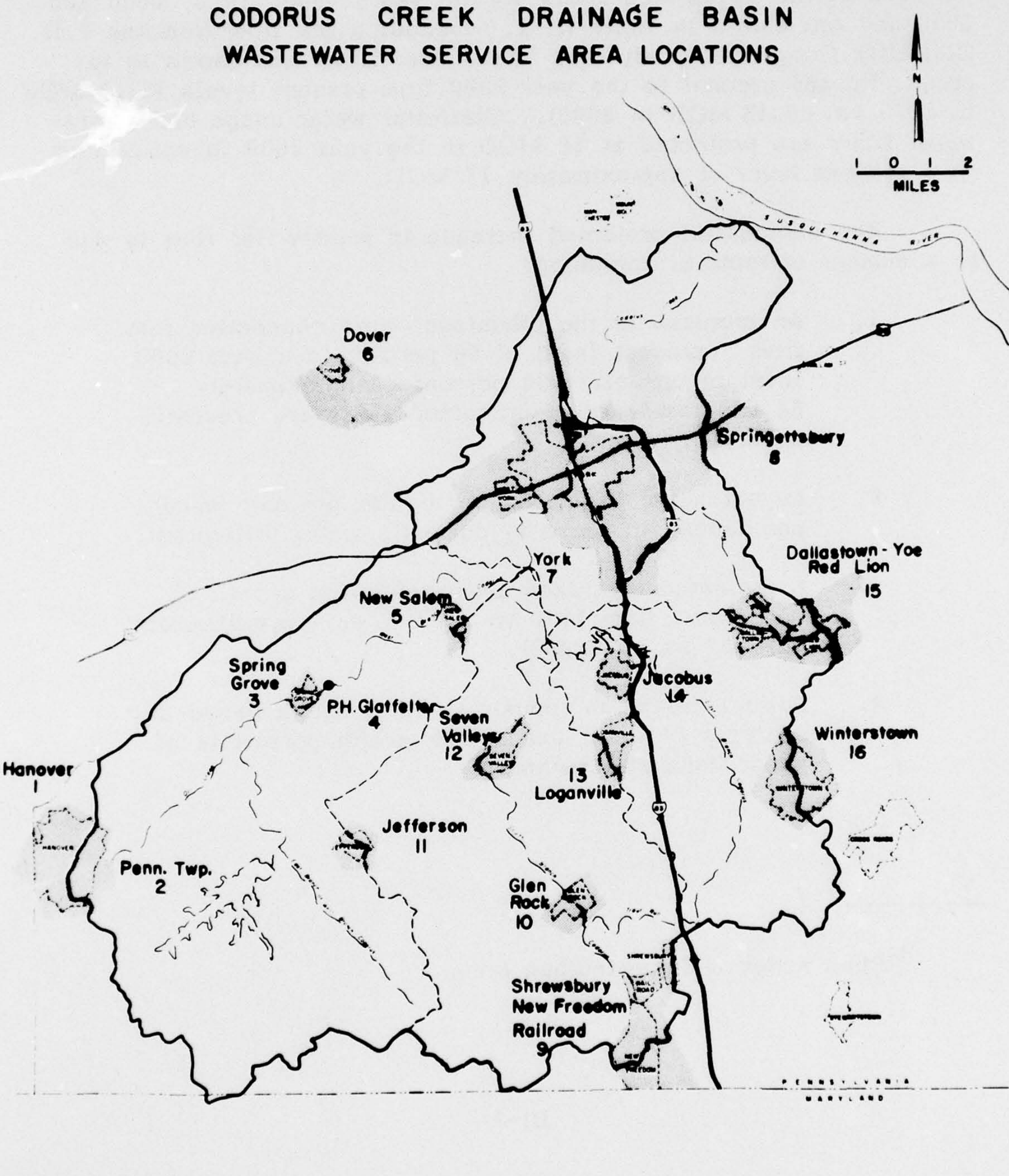
The total area encompassed by the study includes all of the Codorus Creek Basin and the adjacent urban and urbanizing areas that relate directly to the Basin. These related areas include Hanover, Dover and Winterstown. Exhibit III-1 identifies the 16 wastewater management service areas.

Planning Period

The design planning period for all wastewater system alternatives is the year 2000. All transmission and interceptor pipelines are sized and costed for the flows projected for that design year. Treatment facilities are sized and costed as periodic shorter design period investments to meet 1985 and 2000 flows. However, treatment facilities for the small service areas projected to have negligible growth are sized for the year 2000 condition. Selection of different investment periods for transmission vs. treatment facilities is based on the fact that economies of scale are substantial for transmission and major interceptor pipelines. In comparison, economies of scale are substantially less for treatment facilities which are subject to obsolesence with new technology development and refinement. This is particularly relevant for the existing state of the art in advanced waste treatment.

EXHIBIT III-1

CODORUS CREEK DRAINAGE BASIN
WASTEWATER SERVICE AREA LOCATIONS



Wastewater Flow Projections

Wastewater system design flow projections have been developed for each of the 16 service areas for the years 1980, 1990, 2000 and 2020 and are shown in Table III-1. Excluding the flow from the P.H. Glatfelter Co., total study area wastewater flows are shown to increase by 165 percent to the year 2000 from present levels (23.8 MGD in 1970 vs. 60.15 MGD in 2000). Glatfelter water usage and wastewater flows are projected at 28 MGD in the year 2000 in comparison to a present level of approximately 17 MGD.

The substantial projected increase in wastewater flow is due to a number of factors, including;

1. An increase in the urbanized[1] area connection rate from a present level of 68 percent to a year 2000 level of virtually 100 percent. Approximately 54,000 residents of urbanized areas are presently unserved.

2. An estimated 8 gallons per capita per day (gpcd) per decade increase in domestic water utilization.

3. A projected urbanized area population growth of 88 percent from 1970 to 2000 (i.e., approximately 167,000 vs. 315,000).

4. Some increase in industrial water usage based on analysis of water usage and growth potentials of major industrial sectors.

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[1] Urban nodes and semi-urban areas.

TABLE III-1

PROJECTED AVERAGE ANNUAL WASTEWATER FLOW GENERATIONS

Service Area	1970[1]	1985	2000
York	19.7	24.2	35.5
New Salem	NA	0.12	0.13
Springettsbury	NA	7.1	9.8
Dover Township	0.15	1.3	2.8
Hanover	2.0	3.0	3.9
Penn Township	1.0	1.6	2.2
Spring Grove	0.10	0.25	0.30
P. H. Glatfelter Co.	17.2	24.3	28.0
New Freedom-Railroad-Shrewsbury	0.25	1.2	1.9
Glen Rock	0.20	0.30	0.50
Red Lion-Dallastown-Yoe	0.43	1.9	2.7
Winterstown	NA	0.03	0.03
Jacobus	NA	0.18	0.24
Loganville	NA	0.12	0.17
Jefferson	NA	0.03	0.04
Seven Valleys	NA	0.06	0.07
TOTALS	41.0	65.7	88.3

[1] Includes actual STP flows and direct industrial discharges.
NA - Not applicable: service area not in existence during 1970.

II. WATER QUALITY MANAGEMENT OBJECTIVES

The bases for the control of waste discharges in a basin are the uses to be protected and enhanced for the waters affected by the discharges. For the Codorus Basin, present waste discharges affect most of Codorus Creek, the Susquehanna River and, to some uncertain extent, the waters of Cheasapeake Bay.

Under the present federal and state programs for water quality management, the level of treatment performance required of waste discharge sources is determined by the allowable concentration of specific constituents that will not interfere with the pursuance of the uses established for a particular water course.

The Commonwealth of Pennsylvania has developed groups of protected uses for all of the surface waters in Pennsylvania. All of the surface waters of Codorus Creek are designated for the highest uses encompassing game fish, domestic water supply and water contact sports. However, due to natural temperature management limitations, most of the basin is designated for warm water fish. The East Branch and the East Branch of the West Branch are the only units designated for cold water fish.

Water Quality Stream Standards

The water quality criteria for streams adopted by the Commonwealth of Pennsylvania are summarized in Exhibit III-2. Group A criteria are considered applicable for a cold water or trout fishery while Group B criteria are considered adequate to sustain a facultative or warm water fishery.

There are also a number of specific criteria not in the standard groups. These include: turbidity, odor, cyanide, sulfate, chloride, phosphates, color, various metals, etc. Of these, only the color criteria has been established for Codorus Creek as a result of the color problem produced by the P. H. Glatfelter paper mill.

EXHIBIT III-2

WATER QUALITY CRITERIA

Water Characteristics	Criteria Groups: Group A		Group B	
1. pH	al	6.0 to 8.5	al	6.0 to 8.5
2. Dissolved Oxygen	bl	Minimum daily average 6.0 mg/L; no value less than 5.0 mg/L.	b2	Minimum daily average 5.0 mg/L; no value less than 4.0 mg/L.
3. Total Iron	cl	Not to exceed 1.5 mg/L	cl	Not to exceed 1.5 mg/L
4. Temperature	dl	Not to be increased more than 5° above natural temperatures or to be increased above 58° F.	d2	Temperature not to exceed 5° F. rise above ambient temperature or a maximum of 87° F. whichever is less; not to be changed by more than 2° F. during any one hour period.
5. Dissolved Solids	e	Not to exceed 500 mg/L as a monthly average value; not to exceed 750 mg/L at any time.	e	Not to exceed 500 mg/L as a monthly average value; not to exceed 750 mg/L at any time.
6. Bacteria (Coliforms)	f	For period 5/15 to 9/15, coliforms not to exceed 1000/100 ml. For period 9/16 to 5/14, coliforms not to exceed 5000/100 ml.	f	For period 5/15 to 9/15, coliforms not to exceed 1000/100 ml. For period 9/16 to 5/14, coliforms not to exceed 5000/100 ml.

Existing Action Plans

A pollution abatement implementation plan has been established by the Commonwealth of Pennsylvania for the surface water of the lower Susquehanna, covering York and Adams Counties. This plan calls for a minimum of secondary biological treatment. However, for the Codorus Creek Basin, higher levels of biological waste treatment and provisions for dissolved oxygen enhancement have been stipulated to meet stream quality criteria.

As applied to the Codorus Creek Basin, the abatement plan concentrates on improvement in bacteriologic, dissolved oxygen and color requirements of water quality. Subsequent to the formulation of the implementation plan, a program to reduce phosphorus enrichment of the Susquehanna River was formulated. A requirement for 80 percent phosphorus removal of treatment plants in the Codorus Basin coincident with other plan modification is now in effect.

This immediately effects all existing municipal plants but the Dover and Glen Rock plants and the new Springettsbury Township plant. However, the new Dover Township and New Freedom Borough plants are presently being designed without facilities for phosphorus removal. Exhibit III-3 lists the stipulated discharge conditions and timetable for the treatment plants in the study area.

Performance Criteria

The most stringent of the Commonwealth of Pennsylvania performance criteria applicable to the Codorus Creek Basin are as follows:

Biochemical Oxygen Demand (BOD): $\leq$ 7 mg/l in effluent

Color: $\leq$ 50 units in stream

Dissolved Oxygen (D.O.): $\geq$ 6 mg/l in effluent

Total Phosphorus: $\geq$ 80 percent removal

Exhibit III-3
DISCHARGE CONDITIONS AND TIMETABLE

Plant	Conditions[1]	Order Issued	Compliance Date
Glen Rock Borough	95% BOD_5 Removal, 5/1 to 10/31 90% BOD_5 Removal Remainder of Year	10/2/68	10/2/68
New Freedom Borough[1]	$\leq$15 mg/l BOD_5 $\geq$ 6 mg/l D.O.	5/1/69	Upon Start-Up
Spring Grove Borough	$\leq$ 7 mg/l BOD_5, 5/1 to 10/31 $\leq$14 mg/l BOD_5, Remainder of Year $\geq$ 6 mg/l D.O.	8/2/68	6/30/71
Red Lion Borough	$\leq$10 mg/l BOD_5, 5/1 to 10/31 $\leq$20 mg/l BOD_5, Remainder of Year $\geq$ 6 mg/l D.O.	8/2/68	6/30/71
Penn Township	$\leq$10 mg/l BOD_5, 5/1 to 10/31 $\leq$20 mg/l BOD_5, Remainder of Year $\geq$ 6 mg/l D.O.	8/2/68	6/1/71
City of York	$\leq$ 7 mg/l BOD_5, 5/1 to 10/31 $\leq$14 mg/l BOD_5, Remainder of Year $\geq$ 6 mg/l D.O.	8/2/68	6/30/72
Dover Borough	95% BOD_5 Removal, 5/1 to 10/31 90% BOD_5 Removal Remainder of Year	8/2/68	
Dover Township	95% BOD_5 Removal, 5/1 to 10/31 90% BOD_5 Removal Remainder of Year 6 mg/l D.O.		
Hanover	$<$15 mg/l Total BOD[2] $<$ 2 mg/l P $\geq$ 6 mg/l D.O. $<$25 mg/l S.S.		1/31/75
P. H. Glatfelter	$\leq$ 7 mg/l BOD_5 $\geq$ 6 mg/l D.O.	8/7/68	
	Color in Stream 50 Color Units	8/7/68	6/30/77
Applicable to All Plants:	**Disinfection to 200/100 ml Fecal Coliform as a Geometric Average Nor Greater than 10% of Samples Tested.** Total Phosphorus Reduction of at Least 80% at Time of Major Plant Improvement		

[1] Plant in Design Stage.

[2] Total BOD computed as 1.5 x BOD_5 + 4.5 x NH_3 Concentration.

A comprehensive review of water quality conditions in the Codorus and downstream waterways in relation to present and projected future discharge conditions has been conducted as part of this study. This analysis has identified the need to ultimately incorporate ammonia and total nitrogen removal as well as increased phosphorus removal in a water quality management plan that will lead to full protection of Codorus Creek and the Susquehanna River. An ultimate goal of the maximum removal of pollutants with technology available should be considered as a management objective due to the magnitude of total discharges in relation to natural flow.

The management plan must also deal with the "quantity aspect" of water in the Basin. Without a program for substantial reuse and water conservation, deficiencies can be expected in the in-basin availability of municipal and industrial supplies before the year 2000.

A program to manage the quality aspects of stormwater runoff (urban and rural) and the discharge of nutrients from agricultural activities is also required.

An even more critical and more immediate impact of limited water supplies is the reduction of natural stream flow through York resulting from water supply diversion. The community objective of restoring the stream bed of Codorus Creek through York into an environmental amenity requires that flow augmentation opportunities be incorporated in the formulation and review of alternative plans.

Additional performance factors that must be considered in the formulation of management alternatives include the control of potential viral and bacteriologic pathogens and the periodic problem of treatment plant upsets. Pathogens are of particular concern with respect to present and future municipal treatment plant discharges located upstream of the York Water Company intake. Pathogens are also of general concern throughout the Basin and in the Susquehanna River due to the objective of enhancing water quality conditions conducive to full body contact recreational activities.

Upsets of biological treatment plants are a frequent phenomena which most plants experience a few times each year. They can be caused by several factors, including an overload of the treatment plant capacity by stormwater or destruction of the biological organisms by toxic substances in the wastewater. Upsets result in a loss of

effectiveness of the treatment plant and a resulting release of untreated waste in the effluent. Upsets are critical problems in areas, such as in the Codorus Basin, where treatment plant discharges exceed the natural flow. When normal effluent and stream quality is high, upsets cause severe shocks on the environment which are readily observed and lead to adverse public reaction. Consequently, as the general level of water quality conditions is improved, periodic upsets are more difficult to hide or ignore.

Comprehensive review of water quality management conditions and problems in the Codorus Basin, in light of area growth and environmental management objectives to be achieved over the planning period, has led to a more extensive and restrictive set of proposed treatment systems performance criteria. Although the area may not wish to achieve the highest level of performance at the present time, these criteria provide the long-range framework within which facilities development decisions must be made.

Specific performance criteria factors and concentrations proposed for wastewater discharges and for evaluation of alternatives are as follows:

Parameter	Criteria
BOD -	≤ 4 mg/l
Suspended Solids -	≤ 5 mg/l
Total Phosphorus -	≤ .2 mg/l
Ammonia Nitrogen -	≤ .5 mg/l
Total Nitrogen -	≤ 2 mg/l
Color	≤ 50 units
Viral & bacteriologic Pathogens -	Consistent complete removal
Frequency of Treatment Plant Upsets (discharge concentrations greater than 10 x above numbers continuously for one day or longer)	Less than once in five years

Consistency of performance by individual treatment plants should be such that the specific discharge concentrations shown above are achieved at least 95 percent of the time. This dictates that high level performance capability under peak flow conditions must be the governing design condition for individual advanced treatment processes where process capability and performance objectives approximate each other.

III. TECHNOLOGICAL ALTERNATIVES

Range of Technological Choice

The basic technologies available that can meet the long range wastewater treatment objectives posed for the Codorus Basin encompass advanced water process treatment which links complex physical, chemical and biological processes, and land treatment through irrigation which utilizes the multi-process dynamics of the natural soil environment.

Advanced water process technologies available include biological and physical-chemical process-based systems. Process grouping, performance and cost aspects of both alternatives are reviewed in this report.

Alternative available land treatment processes include low-rate spray irrigation, infiltration ponds and overland flow systems. Only the low-rate spray irrigation system is considered suitable in the Codorus Basin area due to a combination of soil conditions and performance objectives.

Performance Capability of Processes

Both the land treatment system and combinations of advanced water process treatment units are capable of achieving the high levels of BOD, suspended solids, ammonia, total nitrogen and phosphorus removal required in the Codorus Basin. However, certain comparative performance aspects of each technology differs from the other. These special aspects of performance, as well as the general performance capability of each technology, are reviewed below:

Advanced Water Treatment Processes

Advanced water process technology is comprised of a group of unit processes which are capable of removing or converting certain specific constituents of wastewater which are not normally removed by conventional secondary treatment. Certain of these processes are largely single constituent oriented (i.e., chemical precipitation of phosphorus) while others are capable of removing a number of pollutants (i.e., filtration for BOD, suspended solids and insoluble phosphorus removal).

Advanced treatment of municipal and industrial wastes in the Codorus Basin necessitates the ultimate grouping in series of a number of process steps to achieve the high levels of ammonia, total nitrogen, phosphorus, BOD, suspended solids and pathogen removals specified.

Ammonia Removal - Ammonia concentrations in municipal effluents are typically in the concentration range of 5 to 15 mg/l, although the data in Table III-2 show a range of 0.10 to 3.81 for a limited number of samples in the Codorus Basin. As discussed in the Phase II report, ultimate long range objectives indicate the need for reduction of ammonia discharge concentrations to 0.5 mg/l or less.

Presently, three methods are available for ammonia removal: ammonia stripping, selective ion exchange, and microbial nitrification (conversion to nitrate). For large scale systems, only ammonia stripping and microbial nitrification are competitive in cost.

Recent experience with plant-scale ammonia stripping systems have documented an inability to maintain high level process performance during the colder months of the year. This is attributed to the increased solubility of ammonia in water at low temperatures and to operational difficulties with stripping towers in cold weather. The aerobic nitrification sludge system appears to offer a more consistent year-round performance, although this system also suffers from some reduction in performance at colder temperatures. It also must be recognized that no operational experience exists for this process on other than the small scale demonstration level. However, the sludge system was selected as the process for achieving ammonia conversion for water process treatment in this study as it appears to be the best available process.

Total Nitrogen Removal - The process for removal of total nitrogen must be selected in conjunction with ammonia removal or conversion. The nitrogen removal process that is most complimentary to the ammonia nitrogen conversion process selected is the denitrification sludge process incorporating the use of methanol for biological reduction (denitrification) of the nitrate compound. This process was selected in preference to the accomplishment of denitrification in the mixed media filter. This latter process would conflict with the chemical treatment flocculation step for phosphorus removal discussed subsequently. Reductions in total nitrogen discharges to 2 mg/l or less are achievable with this process. Like the ammonia conversion process, there are no existing large installations using this process from which reliability evaluations can be made.

TABLE III-2

NUTRIENT CHARACTERISTICS
MEDIAN VALUE CONCENTRATION FOR SAMPLES ANALYZED

SURFACE WATER STATIONS	ORG.N	NH_3-N	NO_2-N	NO_3-N	TOTAL-N	ORTHO-PHOS.	TOTAL-PHOS.
COR 001	1.51	0.51	0.20	3.1	5.31	0.53	1.04
COR 007	1.67	0.59	0.11	1.9	4.27	0.55	0.9
WCO 019	1.71	0.53	0.13	1.9	2.03	0.06	0.23
WCO 024	2.23	0.85	0.12	1.3	4.5	0.05	0.30
WCO 028	1.17	0.04	0.04	1.6	2.85	0.48	0.54
SCO 000	0.55	0.01	0.01	1.85	2.42	0.03	0.07
SCO 014	0.42	0.001	0.01	1.6	2.03	0.08	0.13
FCO 000	0.90	0.08	0.02	1.3	2.33	0.01	0.04
MIL 000	0.79	0.05	0.11	4.6	5.55	0.63	0.76
MIL 008	1.17	0.65	0.44	7.4	9.66	3.5	4.2
OIL 000	1.01	0.11	0.07	2.8	3.99	0.58	0.75

WASTEWATER TREATMENT PLANTS		ORG.N	NH_3-N	NO_2-N	NO_3-N	TOTAL-N	ORTHO-PHOS.	TOTAL-PHOS.
Springettsbury	COR 005	6.77	2.78	0.37	0.52	10.44	2.0	2.75
York	COR 009	11.92	3.78	0.25	0.57	16.52	4.2	7.9
P.H.Glatfelter	WCO 025	4.20	3.81	0.04	0.49	8.54	0.04	0.17
Spring Grove	WCO 026	5.27	3.13	0.03	5.5	13.93	5.0	10.0
Glen Rock	SCO 015	1.68	2.52	0.07	7.4	11.67	8.1	9.4
Red Lion	MIL 009	15.07	2.83	0.17	4.0	22.07	14.0	14.0
Penn Twp.	OIL 006	3.82	0.10	0.01	0.24	4.17	2.6	9.3

NOTE: All concentrations in mg/l.

DATA SOURCE: U. S. Environmental Protection Administration special survey of Study Area, September, 1971.

SAMPLE BASE: Approximately four observations at each station.

80-Percent Phosphorus Removal - Accomplishment of this level of phosphorus removal can readily be achieved through the addition of one of a number of phosphorus precipitation chemicals in the primary or secondary units of secondary treatment plants. Alternative chemical choices include ferric chloride, ferric sulphate, alum and lime. Alum would be the preferred chemical as it produces the minimum addition of undesired salts from the chemical substitution process involved in precipitation.

98-Percent Phosphorus Removal - Consistent removal of phosphorus at this level to reduce effluent phosphorus concentrations to 0.2 mg/l or less after final filtration requires a special tertiary chemical treatment step utilizing high chemical dosages with optimum mixing and flocculation actions followed by sedimentation and filtration. Alternative chemicals include lime and alum. The heavy dose of chemical required and the significant disposal problem posed by the light alum waste sludge has led to the selection of lime treatment coupled with lime recovery through recalcination as the preferred treatment process.

Residual BOD & Suspended Solids Removal - Filtration in multimedia systems provides the most consistent residual BOD and suspended solids reduction for secondary effluents. BOD reduction is achieved through the removal of the portion of the BOD in the non-soluble suspended particle form which represents up to 50 percent of the total BOD in a good secondary effluent. Effluent BOD concentrations of 3 mg/l are achievable with filtration of chemically flocculated secondary treated wastes. Filtration after chemical treatment for phosphorus removal increases the total removal efficiency by filtering out the finely suspended chemical flocs that overflow the chemical sedimentation basins.

Land Treatment Processes

The land treatment system, operated as a low-rate spray irrigation process on crop or forested land, utilizes the soil mantle as a multi-process "living filter." Properly designed, the highest level of tertiary treatment is achievable of all available processes short of distillation. In the soil mantle, or "living filter", a multiple group of processes are operative simultaneously which include:

- physical filtration
- ion exchange
- crop uptake
- volatization
- adsorption
- chemical precipitation
- chemical complexing

The performance of the soil process can be most concisely summarized by examining the fate of each constituent that might come into contact with the soil via wastewater irrigation.

Suspended solids are removed by the array of mechanisms one ascribes to dispersed media filters, i.e., screening, entrapment, gravity forces, coagulation and flocculation and Van Der Waal forces. Organic suspended solids thus captured by the soil mantle slowly break down and solubilize and are converted through microorganism metabolism to new organic cell matter and gaseous carbon dioxide. The new organic matter and the inert residues, together with the inert suspended solids that are also captured, accumulate slowly in the soil mantle. The solid, but organic, content of soils, with or without irrigation, solubilizes and is lost to the soil mantle at a net rate of three to four percent per year. The critical design consideration for an application rate of suspended solids via irrigation is that the soil system does not become clogged and that the rate of organic deposition does not exceed the eventual assimilation capabilities of the soil microorganisms. The literature is replete with documentation[1] indicating that pre-treated wastewater, such as characterized by municipal secondary effluent, does not begin to strain the soils assimilative capacity for suspended solids.

Dissolved organics including organic nitrogen constituents and those constituents characterized as biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), organic-derived color, oils and grease are removed in the soil mantle by means of an adsorption mechanism. Two widely different components in the soil are capable of this adsorption mechanism. One of the components, microorganisms, must absorb the dissolved organics into their exterior enzyme system in order to pre-process the dissolved organics for subsequent metabolic uptake in which new cell matter and carbon dioxide are the final products. The latter part of this process requires aerobic soil conditions. The second soil component, clays, are also capable

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[1] A substantial literature on the land treatment of sewage is contained in the bibliography of the following reports:

1. Penn State Studies, "Wastewater Renovation and Conservation," (Administrative Committee on Research, Pennsylvania State University, 1967).
2. U.S. Army Corps of Engineers, "Wastewater Management by Disposal on the Land," (Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, February 1972).

of absorbing dissolved organics much like activated carbon absorbents. The organics sorbed on such clays are, in a sense, stockpiled for subsequent processing by microorganisms. In this case, however, the microorganisms must be mobile since the organic molecules remain fixed to the clay absorbent until completely assimilated by microorganisms. In the case of either absorbent, the uptake of organics can be quite rapid. A substantial literature testifies to the adequacy of the soil process for easily assimilating dissolved organics in the range of concentrations encountered in municipal secondary effluents.

Nitrogen, in the form of ammonia and nitrates and nitrites, is captured by a variety of mechanisms and is the constituent in wastewater that limits the overall irrigation application rate of a typical municipal secondary effluent wastewater. Ammonia nitrogen is captured by an ion exchange mechanism, commonly referred to as the cation exchange capacity of the soil, which is particularly manifested by organic and clay components in the soil mantle. This mechanism is capable of capturing other cations as well as the ammonium ion, but maintains a rechargeable selectivity for the ammonium ion large enough to give the soil mantle a nitrogen banking capacity against the future distributed nitrogen demands of the growing crop. This is the soil property that permits the farmer to apply his fertilizer in discrete amounts and still supply the distributed demand of his crops. The ammonia nitrogen is subsequently attacked by nitrifying microorganisms during the spring-to-fall period of the year and converted to nitrate nitrogen which is no longer held by the soil mantle but is instead free and mobile and capable of migrating to the crop roots where it is assimilated by the growing crop.

Not all of the nitrate nitrogen is absorbed by the crop roots, however, and this balance, together with any nitrite nitrogen, is free to migrate down towards the groundwater sump below the soil mantle. Along the way, the nitrate and nitrite nitrogen will encounter denitrifying bacteria that will, as long as a source of dissolved organic carbon is available, partially reduce the oxidized nitrogen forms to nitrogen gas and manufacture some new organic cell material. The remainder of unreduced nitrate and nitrite nitrogen will eventually migrate to the groundwater table where further change will cease.

Some of the ammonium ion stored in the soil mantle will also be the nitrogen source for the new microbial cells formed by aerobic synthesis in the upper soil mantle. If more dissolved organic carbon substrate were available in the irrigated municipal secondary effluent wastewater, a much more significant portion of the total nitrogen applied in

irrigation would report to microbial synthesis. Present well-managed fertilizer strategies, as applied to agricultural crops, regardless of whether the fertilizer source is commercial chemical or irrigated municipal secondary effluent, appears to permit a residual of approximately ten percent of the applied nitrogen to percolate through to the groundwater. While this residual concentration is below any problem-causing concentration, it nevertheless is a waste of a resource.

It is possible that regional wastewater management, through its bringing together of municipal and industrial waste residues, will produce a combined irrigable wastewater with a higher overall carbon-to-nitrogen ratio that will materially affect the nitrogen dynamics within the soil mantle and that will likely affect the governing rate of total irrigating water per acre per year. Most industries producing an organic waste have a wastewater that is nitrogen deficient as contrasted with municipal secondary effluent.

The evidence in the agricultural literature[1] demonstrates that nitrogen applications in practical balance with crop uptakes yield agricultural drainage water with up to 2 mg/l nitrogen representing ten percent of the applied nitrogen. While it is possible to produce much higher nitrogen concentrations in the drainage water consistent with much higher rates of application, this practice does not reflect good management, regardless of whether the source of nitrogen is commercial fertilizer or pre-treated wastewater.

Phosphorus, in the soluble form as orthophosphate, is removed in the soil mantle by adsorption/ion exchange on soil clay constituents. In acid soils, the phosphorus absorbing constituents are primarily aluminum and iron. In basic soils, the calcium and magnesium content of the clays can contribute strong adsorption sites for phosphorus. There is always an equilibrium amount of soluble phosphorus present in the soil solution from which the crop is able to derive its requirements through the root structure. Phosphorus is applied at a rate which exceeds the crop uptake and thus the soil is called upon to act as an ultimate sink for phosphorus.

The active adsorbing components in the soil clays at any one time are only an estimated ten percent of the total components within

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[1] Ibid.

the soil potentially capable of adsorbing and holding phosphorus. Once the immediate phosphorus adsorbing capabilities of the soil have been saturated, a resting period, such as the winter non-irrigation season, is required to permit the chemical equilibria within the soil mantle to readjust and produce new active phosphorus adsorption sites. Complete adsorption activity is recovered within three to six months.

From a short-term equilibrium adsorption consideration, the range of sandy to clay soils and their respective depths that have been encountered have exhibited phosphorus removal lives of ten to one hundred years. From the standpoint of the long-term equilibrium adsorption capabilities of this same soil range, allowing for appropriate rest and recovery periods, the phosphorus removal life of these soils is between one hundred and one thousand years. The capabilities of the soil to adsorb and hold phosphorus is evident both from the literature and from the residual concentrations of phosphorus in groundwater in agricultural areas. In well designed irrigation systems using municipal secondary effluents, it is possible to produce an agricultural drainage of reclaimed water with background phosphorus concentrations of 0.01 mg/l.

Bacteria, virus and pathogens are removed by the same mechanisms as cited for suspended solids since they are, indeed, microscopic suspended solids. Various investigations have determined that, once these constitutents have been captured in the soil mantle, they do not long persist. Apparently, the soil environment is not conducive to their survival, perhaps because the indigenous soil microorganisms are too acclimated and competitive to permit a less than indigenous species to survive. A properly designed soil process irrigation system is capable of doing a one hundred percent effective job of disinfection.

Heavy metals are ion exchange/adsorbed by the clay constituents of soils and are chelated by the organic constituents of soils. Once captured by the soil, they are held irreversibly in the normal soil experience, requiring varying degrees of acidic leaching to effect their release. Within certain limitations prescribed by agricultural experience, small residual concentrations of most metals are compatible with soils and can be substantially completely removed by soils. As the organic concentration of soils decomposes, new solid organic matter is being formed along with the deposition of more clays, so that in a "living filter" type of soil system there appears to exist an unlimited life sink for controlled amounts of heavy metals.

Chlorinated hydrocarbons, pesticides and phenol-like substances are captured in the soil by adsorption mechanisms much like other dissolved organics and subsequently converted to new cell material and gaseous carbon dioxide by aerobic microorganisms. The acceptable concentration of these constituents in the soil and wastewater system must be substantially controlled and regulated by pre-treatment, however, much like the limitation on heavy metals. These organic species are largely inimical to the soil microorganisms, and to abuse the soil system with an overload would eliminate the very microorganisms that accomplish the adsorption, and ultimate disposal. The pre-treatment afforded by the municipal biological system in producing a secondary effluent is sufficient guarantee against excessive concentrations of these species.

Total dissolved solids, exclusive of the species heretofore discussed, pass through the soil process unaltered. Typical of constituents in this category are sodium, sulfate and chloride. Potassium is largely extracted by the crop root system for crop growth.

Design Basis of Treatment Processes

The design basis for advanced wastewater treatment processes must be established through the evaluation of the quantitative relationships between process dynamics and performance objectives. The performance objectives for treatment efficiency formulated for the Codorus Basin require consistent, high-level performance by treatment components. For water based advanced treatment processes, a high sensitivity of treatment efficiency exists with respect to process flow rates. As a result, these processes must be designed to provide the desired treatment performance at peak rates of flow frequently encountered.

For the land treatment system, the low rates of application in relation to the process capabilities of the soil treatment system for removal of organic material greatly mitigates the effects of variations in the secondary treatment performance required prior to land application.

Design criteria for treatment processes are listed below for the specific systems and processes considered in this study:

Water Process Systems

Hydraulic Plant Flow Regulation - Regulation of treatment plant flows for advanced treatment processes to a maximum of 1.7 x average daily flow through provision of storage prior to or after secondary treatment.

<u>Secondary Treatment</u> - Design parameters dependent upon biological process chosen but must be capable of controlling BOD and suspended solids discharges to less than 20 and 25 mg/l, respectively, at average flow condition.

<u>80 Percent Phosphorus Removal</u> - System capable of an average of at least 80 percent total phosphorus removal on an average daily basis.

<u>High Level Advanced Waste Treatment Processes</u> - Systems designed to achieve rated performance at maximum flow. Specific performance and design aspects are tabulated below:

Process	Treatment Performance	Design Factors
Nitrification	$NH_3 \leq 0.5$ mg/l	Aeration sludge system - 3 hours detention at peak flow
Denitrification	Total N ≤ 2.0 mg/l	Anaerobic sludge system - 3 hours detention at max. flow; methanol added for process stability
98 Phosphorus Removal	Total Phosphorus ≤ 0.2 mg/l	Chemical flocculation and settling with lime dosages up to 400 mg/l for rated performance
Filtration	$BOD_5 \leq 4$ mg/l Sus. Solids ≤ 3 mg/l	Mixed-media filtration at loading rates not to exceed 6 gpm/ft^2 at maximum flow
Physical-chemical treatment with lime clarification, carbon adsorption and filtration	$BOD_5 \leq 3$ mg/l Sus. Solids ≤ 3 mg/l Total Phosphorus ≤ 0.2 mg/l	Countercurrent flow system using granular carbon - 6 gpm/ft^2 process flow rate

Land Treatment System

The land treatment system as considered for the Codorus Basin was evaluated with the following design criteria.

Pre-treatment of wastes - conventional or aerated lagoon secondary treatment

Application rate: 2" per week - 8 mo/yr.

Land Requirements - 194 net irrigation acres per MGD average annual flow

Winter storage of flows - 4 months storage of total flow

Water Application system - rotating rig or traveling gun systems

Drainage - Sub-surface drainage of irrigated areas using wells or drain tile as dictated by economies and performance requirements

Storage Lagoons - supplemental aeration when total depth exceeds 15 feet.

Estimated nutrient loadings to the land for different rates of application are presented in Table III-3.

Alternative Municipal Treatment System Descriptions and Performance Capabilities

A number of different treatment system types are categorized in this report to reflect a range of performance options and alternative technologies appropriate to achieving each performance level. System process configurations selected for the lower performance levels are those that can be easily upgraded to higher performance levels with minimum loss of initial investment.

A total of six treatment system types have been developed . These include:

Treatment Type	Principal Process Basis	Level of Performance
A	biological	secondary
B	"	low level advanced
C	"	medium level advanced
D	"	high level advanced
E	physical chemical	high level advanced
F	soil treatment	high level advanced

Table III-4 lists the component elements for each type. Flow charts for each are also shown. A tabulation of specific performance capabilities of each system is summarized in Table III-5.

Technology Alternatives - P. H. Glatfelter Paper Company

The raw liquid waste stream from the P. H. Glatfelter Company (PHGCo) integrated bleached kraft production facility is presently comprised of approximately equal volumes of pulp mill wastes and paper mill wastes. Pulp mill wastes contain the solubilized lignins and characteristically have high color, COD and dissolved solids concentrations, and occasional moderate BOD and suspended solids concentrations. Paper mill wastes contain moderately high COD and suspended solids concentrations, moderate BOD and dissolved solids concentrations and occasional moderate color concentrations due to production of color paper stock. The process water flow internal to the PHGCo integrated facility is considerably higher than the net inflow and outflow of raw water and wastewater, respectively, because of extensive recirculation and reuse of paper mill process water.

The present PHGCo treatment facilities which provide a high secondary effluent quality (BOD_5 = 10 mg/l) have a capacity of 20 MGD compared to a current flow of 17 MGD. Specific processes include primary clarification with chemical treatment using lime and biolobical treatment by an aerated lagoon activated sludge system.

TABLE III-3

NUTRIENT LOADINGS OF
YORK METROPOLITAN AREA
SECONDARY TREATMENT PLANTS
(YORK & SPRINGETTSBURY STP'S)

Parameter	Survey Data mg/l	Design Basis		Lbs/Acre	
		mg/l	lbs/mg	2"/wk 8-mo.	3"/wk 8-mo.
Ortho Phosphorus	4	4	34	65	97
Total Phosphorus	7	7	59	112	168
Ammonia Nitrogen	4-8	6	50	95	142
Organic Nitrogen	2-11	7	59	112	168
Total Nitrogen (All forms)	11-15	13	109	208	310
Potassium	10	10	83	158	236

TABLE III-4

ALTERNATIVE TREATMENT SYSTEMS AND COMPONENT PROCESSES

A. Type A Conventional Secondary (Exhibit III-4, page IV-132)

1. Contact stabilization or aerated lagoon secondary followed by clarification.

2. Addition of alum to secondary to achieve 80% phosphorus removal.

3. Chlorination sufficient to reduce total coliform to less than 1000/100 ml.

4. Digestion of waste sludge in an aerated lagoon with capacity for 15 days detention with covered storage to 120 days in winter; digestor supernatant is intermittently recycled to the contactor or aerated lagoon; digested sludge is spread to land.

B. Type B Low Level Advanced (Exhibit III-5, page IV-133)

1. Secondary treatment as in Type A.

2. 80% phosphorus removal as in Type A.

3. Filtration through sand or graded media with intermittent backwash recycled to contactor or aerated lagoon.

4. Reaeration to increase dissolved oxygen concentration from approximately 1 mg/l to 6 mg/l.

5. Chlorination as in Type A.

6. Sludge digestion and disposal as in Type A.

TABLE III-4 (Cont'd)

C. Type C Medium Level Advanced (Exhibit III-6, page IV-134)

1. Secondary treatment as in Type A.

2. 80% phosphorus removal as in Type A.

3. Nitrification by biological action in an activated sludge process.

4. Denitrification by biological action in an anerobic activated sludge process; methanol must be added as a source of carbon.

5. Filtration as in Type B.

6. Reaeration as in Type B.

7. Chlorination as in Type A.

8. Sludge digestion and disposal as in Type A.

D. Type D High Level Advanced (Exhibit III-7, page IV-135)

1. Secondary treatment as in Type A (without phosphorus removal).

2. Nitrification as in Type C.

3. Denitrification as in Type C.

4. Phosphorus removal by massive lime addition followed by clarification; lime is recalcined in fluidized-bed incinerators; make-up lime added.

5. Recarbonation by addition of CO_2 from recalcination; $CaCO_3$ sludge formed is recycled to incinerator.

6. Filtration as in Type B.

7. Reaeration as in Type B.

8. Chlorination as in Type A.

9. Sludge digestion and disposal as in Type A.

TABLE III-4 (Cont'd)

E. Type E High Level Physical/Chemical (Exhibit III-8, page IV-136)

1. Chemical precipitation of primary with massive lime addition followed by clarification; lime is recalcined in fluidized-bed incinerators; make-up lime added; ash is wasted to landfill.

2. Recarbonation as in Type D.

3. Adsorption of dissolved organics by passing through beds of granular activated carbon; carbon is regenerated intermittently in fluidized-bed reactors.

4. Ammonia nitrogen removal by passing through beds of clinoptilolite, a natural mineral with selective ion exchange properties; the stripped ammonia is intermittently discharged from the regeneration process, together with air, and is passed through the incinerator to yield largely water and nitrogen gas.

5. Filtration as in Type B.

6. Reaeration as in Type B.

7. Chlorination as in Type A.

F. Type F Advanced Land Treatment (Exhibit III-9, page IV-137)

1. Secondary treatment as in Type A.

2. Winter storage of secondary effluent.

3. Chlorination as in Type A

4. Land irrigation at a rate of 2 inches per week for eight months of the year.

5. Multi-processing by the "living filter" of the soil; nutrients taken up by plants and soil; filtration of suspended solids; heavy metals and residual dissolved organics adsorbed by soil; bacteria, pathogens, and virus removed by filtration/adsorption.

TABLE III- 4 (Cont'd)

6. The underdrain reclaimed water is segregated, collected and distributed as desired.

7. Reaeration where necessary as in Type B.

8. Sludge digestion and disposal as in Type A.

TABLE III-5

COMPARISON OF TREATMENT SYSTEM PERFORMANCE

Treatment Type	Performance Capability - Typical Effluent Quality								
	COD mg/l	BOD5 mg/l	Suspended Solids mg/l	Dissolved Solids mg/l	Phosphorus % rem./ mg/l	Color Pt-Co Units	NH_3-N mg/l	NO_3-N NO_2 mg/l	Organic N mg/l
A	90	20	25	400	80/2	20	17	1	2
B	45	7	3	400	80/2	20	17	1	2
C	30	5	3	400	80/2	20	0.5	2	~0
D	30	4	3	350	98/0.2	20	0.5	2	~0
E	10	3	3	350	98/0.2	<5	0.5	2	~0
F	5	3	~0	400	99/0.05	<5	0.1	2	~0
P.H. Glatfelter at Present	225	12	50	1575	0.2	700	3.5	1	7
P.H. Glatfelter Alt. A	12	4	3	1575	0.2	25	3.5	1	~0
P.H. Glatfelter Alt. B	5	3	~0	1575	0.1	<10	0.1	2	~0

To satisfy the Commonwealth of Pennsylvania effluent restrictions and stream quality objectives the P.H. Glatfelter Co. must improve the quality of its effluent in the following areas.

BOD_5 - reduced to 7 mg/l or less from the present 10 mg/l level

Color - reduce the present stream concentration levels of 300-400 units to less than 50 units. To accomplish this, effluent concentrations must be less than 100 units

Thermal - reduce heat loading so that maximum stream temperatures below the plant do not exceed 87° F.

Dissolved Oxygen - provide reaeration to maintain D.O. above 6 mg/l

The possible treatment technologies that are available to PHGCo in order to accomplish the existing Commonwealth of Pennsylvania's stream and effluent standards are as follows:

A. Chemical clarification with lime followed, in order, by: biological treatment, selective adsorption with activated carbon for COD and color removal, polishing filtration, reaeration combined with evaporative cooling for temperature control, and chlorination. The technical feasibility of the process sequence (illustrated in Exhibit III-10, page IV-138) has been demonstrated and documented in a PHGCo report entitled "P. H. Glatfelter Company - Advanced Waste Treatment Research - Color, BOD, D.O. and Temperature-Compendium and Status" - July 31, 1969.

B. Chemical clarification with lime followed, in order, by: biological treatment, land application (for the simultaneous removal of COD, color, suspended solids, nitrogen and phosphorus together with disinfection and temperature reduction through evaporative cooling) and reaeration. The technical feasibility of this process sequence, (illustrated in Exhibit III-11, page III-139), has been demonstrated and documented in Technical Bulletins #150 and #164 of The National Council for Stream Improvement of the Pulp, Paper and Paperboard Industries and in "Recent Progress In Land Disposal of Mill Effluents," by R.O. Blosser and A.L. Caron, TAPPI 48, 43A-46A (1965).

The absolute control of the nutrients phosphorus and nitrogen by PHGCo Treatment Alternative A is uncertain without specific provision for their removal. However, at present the PHGCo wastewater treatment facility, which provides chemical clarification with lime followed by biological treatment of a nutrient deficient waste, has the capability to control phosphorus discharges to concentration levels as low as that which municipal facilities can achieve with present phosphorus removal process technology.

The phosphorus residual in the present treated effluent has been reported to average less than 0.2 mg/l indicating a significant accomplishment in balance between phosphorus removal prior to the biological process and the phosphorus metabolism requirements of the biological process itself. It is possible that further phosphorus control could be accomplished by the PHGCo Treatment Alternative A together with continued attention to the existing balance between phosphorus removal by chemical methods and by biological uptake.

Similar considerations apply to the nitrogen concentration of the PHGCo treated effluent averaging 10 mg/l of total N of which 7 mg/l is organic-nitrogen, 3 mg/l is ammonia-nitrogen and less than 1 mg/l is nitrate-nitrogen. PHGCo presently adds ammonia at the rate of 7 mg/l of waste flow to the biological process because of a nutrient deficiency in their waste.

PHGCo Treatment Alternative A would eliminate the organic nitrogen. Further control of the ammonia nitrogen and nitrate concentrations by reducing the PHGCo present ammonia nutrient supplement might be possible in order to minimize ammonia toxicity problems for aquatic life in the West Branch of the Codorus and the downstream estuarine eutrophication in the Upper Chesapeake Bay. Failing the further control of phosphorus and nitrogen in the PHGCo treated effluent by the attempts outlined above would ultimately require supplemental nutrient processes to be appropriately added to the PHGCo Treatment Alternative A process sequence in order to accomplish the enunciated water goals of the governments of the Commonwealth of Pennsylvania and of the United States.

The absolute control of the eutrophication nutrients, phosphorus and nitrogen, and the elimination of the ammonia toxicity problems are provided for within PHGCo Treatment Alternative B and therefore no uncertain supplemental process qualifications are necessary.

The other technologies which are potentially available as alternatives to PHGCo Treatment Alternatives A and B and which could control

as well the total dissolved solids concentration of the PHGCo integrated facility are reverse osmosis, ion exchange, electrodialysis and evaporation-distillation. To embark on any of these routes requires ultimate disposal or recycle of the mixed inorganic waste salts resulting from bleached kraft paper manufacture with an associated yearly cost of 10 times that currently incurred by PHGCo for treatment of liquid wastes and 20 times that of any of the many other bleached kraft mills in the United States. A possible more promising future alternative for PHGCo would be a process change to oxygen bleaching which would effectively eliminate chloride and reduce color in the liquid wastes. Oxygen bleaching is still being evaluated by the pulp and paper industry.

Sludge Management Alternatives

Relevant alternatives for management and ultimate disposal of wastewater sludges from urban areas is highly sensitive to institutional and social factors in addition to the normal economic and technical ones. Present practices in the Codorus Basin area, in which most municipal sludges are digested and disposed on the land for crop fertilization, is a low cost solution but also highly sensitive to the cultural atmosphere for acceptance by local farmers.

The present institutional mechanism for land application is largely informal. It is uncertain whether this institutional mechanism will be satisfactory for the increased quantities of sludge produced with area growth depicted in Table III-6.

For water process treatment systems in urban areas, the other alternatives available include sludge incineration, sludge digestion and dewatering with landfill disposal, and purchase of agricultural or reclaimable land for programmed sludge application. All of these other alternatives are substantially more expensive than the present practice.

For the land treatment system, large amounts of land are usually available which are not initially needed for irrigation or which are never irrigated due to the incomplete use of the total site for the types of irrigation systems, typically selected. Where initial wastewater treatment is provided at the irrigation site with complete-mix aerated lagoons, the sludge can be applied to the land in a programmed manner after separation and stabilization.

TABLE III-6

PROJECTED WASTEWATER SLUDGE PRODUCTION - MUNICIPAL WASTES

Service Areas	Dry Solids Production (Tons/day) 1972	1985	2000
York Urban Area	15.8	23.0	33.8
Hanover-Spring Grove Urban Area	2.2	3.2	4.2
Railroad-New Freedom and Glen Rock Urban Area	0.5	1.0	1.6

LAND REQUIREMENTS FOR SLUDGE APPLICATIONS

ACREAGE REQUIREMENTS			
Annual Application of Sludge on Same Land at 25 Dry Tons/Ac		*One Time Application of* Sludge at 250 Dry Tons/Ac	
by 1985	by 2000	by 1985	by 2000
400	580	462	1,197

Two alternatives available for sludge stabilization with the land treatment system include chemical oxidation and digestion in the bottom of the storage lagoons. Storage in the bottom of the wastewater storage lagoons permits the seasonal application of this material through a distribution pipeline.

Costs of Treatment Systems

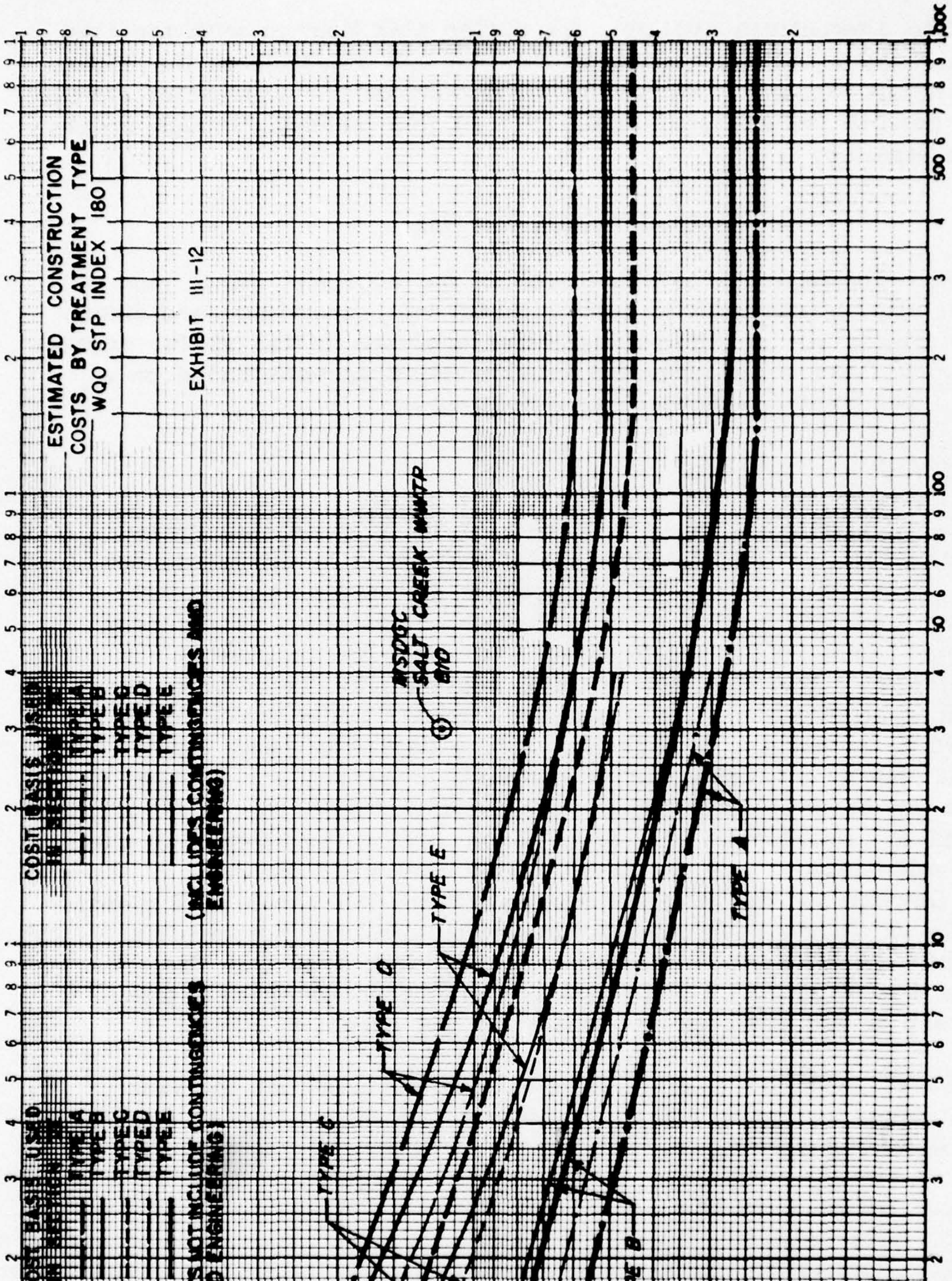
Relevant costs to be considered in the economic comparison of treatment alternatives include capital investment, operating, and final salvage value. To facilitate comparative analysis in this study, average annual costs have been computed for alternative systems based on a 30-year investment period at 6 percent interest.

Capital Costs

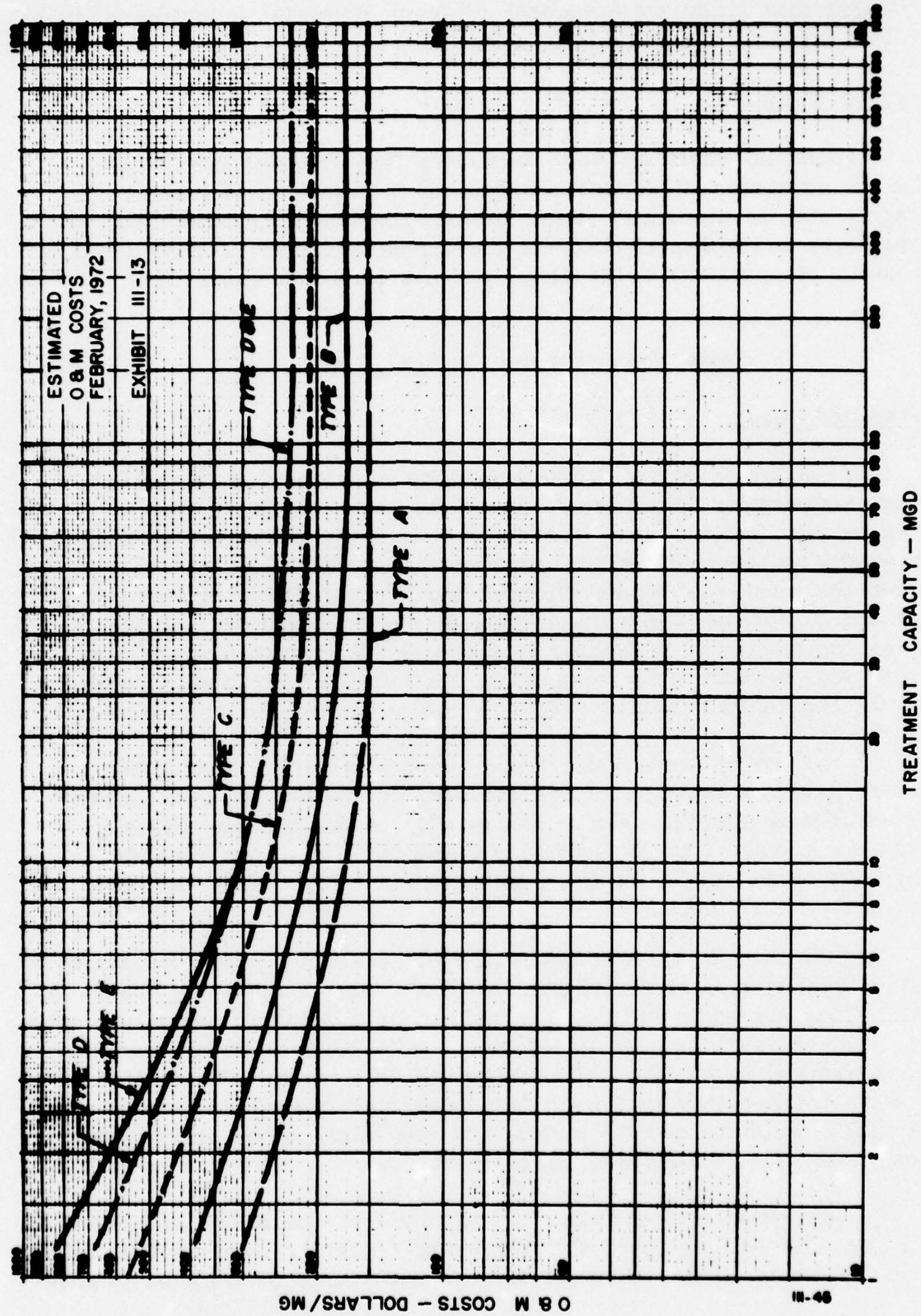
Capital construction cost curves for the five water process-based municipal treatment system types considered in this study are presented by Exhibit III-12. Capital costs shown for conventional secondary treatment facilities are based on actual costs encountered for a large number of facilities of all sizes and are considered representative. In comparison, capital costs shown for many of the advanced waste treatment processes are based on cost projections developed by a number of researchers using data from small pilot treatment plants. Actual costs of advanced processes are considered, therefore, to be subject to considerable variation from the curves developed in this study. This is demonstrated by the plotting of the low bid price received by the Metropolitan Sanitary District of Greater Chicago for the 30 MGD (average flow) Salt Creek AWT plant. This bid, which has been adjusted to delete facilities not directly comparable, is for a plant equivalent to treatment Type C. The bid price was $1,200,000 per MG average flow compared to a projected cost of $580,000 per MG shown by the curve.

Development of generalized capital cost curves for the land treatment-spray irrigation system is not considered appropriate due to the significant variability of cost factors such as:

1. Distance to site
2. Cost of land
3. Land utilization
4. Purchase and relocation requirements for on-site or adjacent residential and other activities
5. Required methods of site drainage
6. Opportunities for development of winter storage impoundments



ESTIMATED CONSTRUCTION
COSTS BY TREATMENT TYPE
WQO STP INDEX 180
EXHIBIT III-12
COST BASIS USED
TYPE A
TYPE B
TYPE C
TYPE D
TYPE E
DOES NOT INCLUDE CONTINGENCIES AND ENGINEERING
INCLUDES CONTINGENCIES AND ENGINEERING
SALT CREEK WWTP
TYPE A
TYPE B
TYPE C
TYPE D
TYPE E
TREATMENT CAPACITY - MGD
CONSTRUCTION COST - DOLLARS /MGD



ESTIMATED
O&M COSTS
FEBRUARY, 1972
EXHIBIT III-13
TYPE D&E
TYPE B
TYPE A
TYPE C
TYPE D
TYPE E
TREATMENT CAPACITY — MGD
O & M COSTS — DOLLARS/MG
III-46

For this study project costs for each potential land treatment site area were evaluated individually.

Operating Costs

Operating costs for each treatment type (Exhibit III-13) are based on estimates of adequate manpower requirements for plant operation and maintenance, power costs, chemical costs and typical maintenance costs experienced for the types of facilities considered. The basis of operating costs developed are listed in Table III-7.

Water Reuse in the Codorus Basin

Wastewater Reuse

Water reuse is an alternative to be considered in preparing a basin wastewater management plan. Reuse decreases demands placed on raw water sources; reuse frequently requires less treatment than would be required for new process water treatment, and reuse reduces the number of waste streams and the quantities of wastewater and pollutants being discharged to the environment. Opportunities for the reuse of treated wastewater (secondary and tertiary quality) will become more relevant in the future as competing demands arise for the limited natural supply available in the Codorus Basin.

A number of large water-using industries in the York Urban area are likely to be able to use the tertiary treated effluent directly for cooling and process uses. The quality of the tertiary effluent will be as good as that of treated surface water in most aspects. Higher dissolved solids for the treated effluent represents the only major quality difference.

A potential major reuse opportunity is present for the utilization of secondary quality municipal effluent as a raw water supply for the P. H. Glatfeter Company paper mill. The significant aspects of the reuse potential are that the mill uses a large amount (17 MGD) of water, and that chemical treatment and filtration is provided this water. Utilization of these same treatment facilities for the secondary treated wastewater can renovate this water to quality levels that are likely to be acceptable as process water for the pulp and paper operations.

A comparison of the chemical and physical quality of secondary treated York STP effluent with the raw water presently used by Glatfelter is shown in Table III-8. A comparison is also made of finished quality

TABLE III-7

BASES FOR OPERATING COSTS

A. Minimum Manpower Requirements

Because of the necessity for proper plant operation, the following minimum manpower was used in calculating system operating costs.

1) Type A with contact stabilization secondary.

0.5 MGD Plant - 3 men full time
1.0 MGD Plant - 4 men full time; 1 man half time

Sludge disposal manpower is supplemental and at a utilization rate of 0.3 manhours/ton of wet sludge.

2) Type A with aerated lagoon secondary.

0.5 MGD Plant - 2 men full time
1.0 MGD Plant - 3 men full time

3) Filtration and aeration

0.5 MGD Plant - 1 man full time
1.0 MGD Plant - 1 man full time; 1 man half time

B. Labor Costs

Assumed 1 man-year, including overhead = $15,000.00

C. Electrical Power

Energy cost at 2¢/kwhr.

D. Chemical Costs

Activated Carbon	40¢/lb
Chlorine	5¢/lb
Alum $Al_2(SO_4)_3.6H_2O$	$90/ton
Lime CaO	$27/ton

E. Cost of electrical power, chemicals and materials and supplies (principally gasoline and natural gas) were assumed independent of treatment capacity.

F. Operating and maintenance costs obtained from Smith[1] when available, or from operation of advanced treatment plants, particularly at Lake Tahoe. Labor costs have been adjusted to meet the herein - presented minimum requirement. Electrical energy costs have also been adjusted where energy costs were significant.

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[1]Smith, Journal Water Pollution Control Federation, 9/68.

TABLE III-8

WATER SUPPLY FOR P. H. GLATFELTER COMPANY

Characteristic	West Branch Codorus Creek	Treated PHGC Process Water	York STP Effluent	Springettsbury STP Effluent	Chemical Treatment of York Effluent*
Turbidity-Std. Turbidity units	10-40	2	36	7	2
Color-Std. Color units	5-25	-	40	25	< 5
Total Hardness as $CaCO_3$	100 mg/l	72 mg/l	164 mg/l		120
Ca Hardness as $CaCO_3$	50 mg/l	52 mg/l	110 mg/l		110
Total Alkalinity as $CaCO_3$	75 mg/l	40 mg/l			-
Iron as Fe	0.1-0.2 mg/l	0.05 mg/l	0.6 mg/l		0.1
Manganese as Mn	0.05-0.1 mg/l	0.03 mg/l	0.1 mg/l		<.05
Silica (Soluble) as SiO_2	20-50 mg/l	5.3 mg/l	9.0 mg/l		5
Total Dissolved Solids	200-200 mg/l	-	370 mg/l	340 mg/l	370
Free Carbon Dioxide as CO_2	10 mg/l	-			-
Chlorides as Cl^-	8 mg/l	9 mg/l	47 mg/l	54 mg/l	47
Sulfate as $SO_4^=$	11 mg/l	40 mg/l	76 mg/l	66 mg/l	76
pH		6.9	7.1		7.0
Suspended Solids	15 mg/l		42 mg/l	16 mg/l	0
Chemical Oxygen Demand as O_2	10 mg/l		130 mg/l	34 mg/l	30

*With improved secondary treatment at York

of the water presently used by the mill with the finished quality obtainable with chemical treatment and filtration of the York STP effluent. Although more extensive chemical treatment will be required than presently provided the West Branch raw water supply, the present installed basic treatment process components of Glatfelter should be adequate. Therefore, although the chemical and related operating costs will be higher, the significant hydraulic capacity related capital and operating costs will not increase. A large part of the annual cost of wastewater and water treatment is associated primarily with the capital investment, power, maintenance and operating costs of handling the hydraulic flow.

The water treatment facilities at the mill should be able to produce a process water from the treated sewage very similar to that which it is now producing from surface water from the West Branch. The alum dose would probably need to be increased to insure adequate removal of color, turbidity, and organic matter; the chlorine dose would need to be raised to insure adequate slime control; and lime would possibly be needed to insure adequate iron and manganese removal. Anticipated chemical feed requirements and costs are shown in Table III-9.

TABLE III-9

WATER TREATMENT CHEMICAL COSTS
P. H. GLATFELTER COMPANY

	River Water Source		Reuse Source		
	Dose Rate mg/l	Cost \$/mg	Dose Rate mg/l	Cost \$/mg	Additional Cost \$/mg
Chlorine	3.3	1.38	5	2.09	0.71
Alum	16.3	6.80	80	33.60	26.80
Lime	0	0	50	0.50	0.50
TOTALS		\$8.18		\$36.19	\$28.01

Chemical feed requirements at the PHGC water treatment plant, should secondary treated sewage treatment plant effluent be used as a raw water source, can be met with equipment now being used to treat raw river water. Operational staff requirements at the water treatment plant would not increase if the sources were changed.

Treated wastewater used as a raw water source would, however, create two additional operating costs. Sludge production could be increased by possibly as much as 20 percent. Hauling and disposing of this sludge could increase treatment costs by as much as $1.00 per million gallons. Automatic monitoring equipment to protect PHGC from sewage treatment plant upsets which would adversely affect raw water quality would be needed. This equipment would continuously monitor pH, COD or TOC, conductivity or TDS, turbidity or SS, and color and be set to give an alarm when any of the above parameters exceed acceptable limits. This equipment would cost about $25,000 and would operate at an annual cost of about $1,500.

Additional synergistic benefits of secondary effluent utilization of Glatfelter relate to the nutrient deficiency aspects of the paper mill wastewater treatment system. Presently, Glatfelter furnishes supplemental nitrogen to its biological secondary treatment system in the form of anhydrous ammonia. Approximately 1,000 lbs per day are added to the 17 MGD process flow. Analysis of the process water utilization at the paper mill indicates that a large part of the total nitrogen present in the secondary York Area effluent (the ammonia and nitrate forms) will remain in the water after treatment at the paper mill and ultimately reach the wastewater treatment plant. Assuming the present 8 mg/l ammonia and nitrate effluent concentration level carried through the paper mill, the total nitrogen added would be 1,300 lbs per day for a projected flow of 20 MGD This would approximately equal the supplemental nitrogen needs of a 20 MGD biological treatment system at the paper mill. The need to provide supplemental nitrogen would thereby be eliminated.

Suitability of Physical Characteristics for Wastewater Applications

Significance of Physical Characteristics

All soils investigated within the Codorus Creek Basin in regions considered for wastewater application have well defined soil profile development. An essential characteristic of this profile development is the presence of a zone of relatively low permeability (generally the B Horizon) overlain and underlain by zones of somewhat higher permeability. In the geologic profiles given for each of the site areas investigated, this layer of low permeability occurs within the uppermost zone of the profile. The thickness of the low permeable zone is variable but ranges up to 10 feet. Commonly, this zone is more than 2 or 3 feet thick and is present to depths of two to six feet below land surface.

The zone of lowest permeability is the primary determinant of the rate at which fluids can infiltrate from land surface to deeper lying levels. Determination of application rates of wastewater must take into consideration the permeability characteristics of this intermediate zone within the application area. Soil permeability determinations based on short-term infiltration tests might not be representative of permeability rates that prevail under wastewater application operating conditions involving spray application. It is important to note that infiltration and permeability characteristics of the soil are affected by a variety of environmental factors that are associated with irrigation practices.

Throughout most of the Codorus Creek Basin, extensive areas of relatively thick soil developments can be identified. Provided these areas have adequate infiltration capacity, the thickness of the soil column is beneficial to the polishing of the infiltrating wastewater. In the area of the Triassic bedrock, however, soil development is characteristically thin -- 3 feet or less -- and the polishing function of the soil is significantly inhibited.

Permeability by virtue of joints, fractures and the enlargement of these by solutioning and weathering are the dominant characteristics of subsurface units in the Codorus Creek Basin. Conditions of intergranular permeability occur only in alluvial deposits, basin fills and in the soil produced by weathering of the indurated bedrock. These materials are generally fine-grained, restricted in occurrence or lie well above the level of groundwater saturation.

The transmissivity (permeability times thickness) characteristics of the subsurface is dependent on the distribution, concentration, orientation and depth of secondary linear openings in the indurated bedrock. Information acquired in the drilling program and from specific capacity data on water wells within the basin indicate that there is a wide range in permeability characteristics within each of the geologic units, that the average level of permeability is in the order of magnitude of one to tens of gallons per day per ft^2 and that the zone of highest permeability is generally restricted to the upper few hundred feet of bedrock.

These characteristics serve to complicate the design of effective subsurface drainage control systems in that analytical techniques for prediction of local groundwater flow paths and transmissivity characteristics are likely to be limited as a predictive tool and that these characteristics probably will have to be determined on an empirical basis at each application site.

Slope conditions within the drainage basin serve to limit the amount of area suited to land application in that a significant proportion of the basin area is at slopes greater than 15 percent. Slopes are generally uniform, however, and as a consequence the areas of gentler slopes tend to form broad continous bands bordered by the areas of steeper slope. Areas of moderate to gentle slope are mainly along the upland drainage divides in the schist and phyllite terrains and on surfaces of the carbonate formations and the Triassic bedrock.

Due to the high relief for most of the basin area, groundwater saturation lies at depths in excess of 20 feet under most of the upland areas. One exception is the low lying upland area at Hanover where, because of the low regional relief, groundwater levels are commonly within 10 feet of land surface.

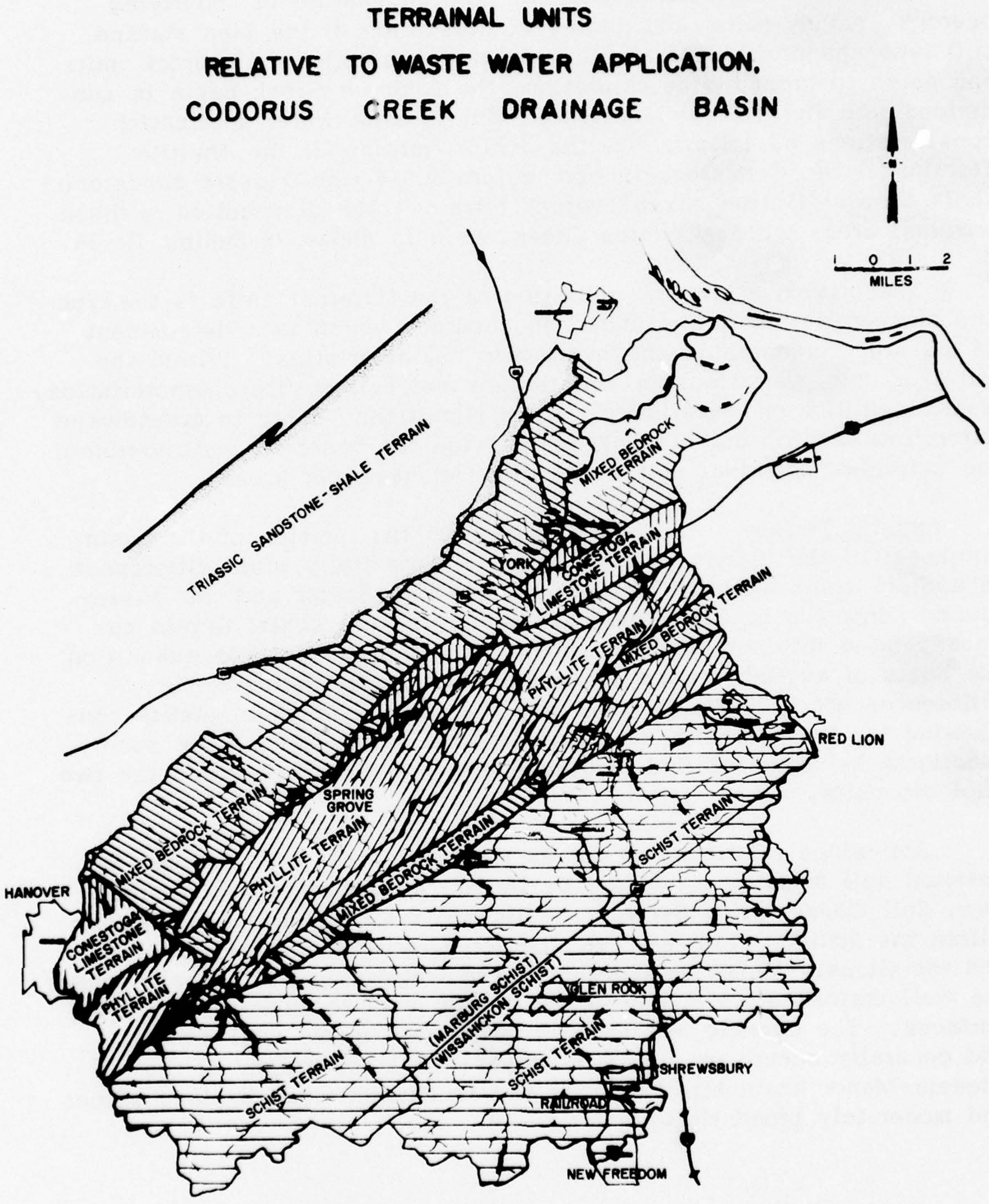
Terrainal Units Relevant to Wastewater Application

On the basis of differences in type and nature of underlying bedrock, slope, relief and degree of dissection of the land surface, soil type and profile characteristics, transmissibility of bedrock units and depth to groundwater saturation, the Codorus Creek Basin is subdivided into five terrainal units relevant to wastewater application considerations as follows: (1) the Schist Terrain; (2) the Phyllite Terrain; (3) the Conestoga limestone terrain; (4) the Triassic sandstone-shale terrain; (5) the mixed bedrock terrain. The distribution of these terrainal areas within Codorus Creek basin is shown in Exhibit III-14.

The primary basis for definition of the terrainal units is the type and characteristics of the underlying bedrock which is a determinant of the soil, topographic and hydrologic characteristics. Within the terrainal unit, variations in soil texture and soil profile characteristics, transmissibility characteristics, slope conditions, depth to groundwater saturation and topographic position provide the basis for subdivision of the individual terrainal unit into various management areas.

Schist Terrain - The Schist Terrain is that portion of the basin southeast of the Martic Overthrust line. Potentially large differences in bedrock transmissivity between the Marburg Schist and the Wissahickon Formation geologic units indicates that the schist terrain can be separated into the Marburg subunit and the Wissahickon subunit on the basis of available specific capacity data. Whether these differences are sufficiently great and persistent enough to justify considering the two subunits as major terrainal units can only be substantiated by more detailed hydrogeologic investigations within the two geologic units.

Soil-slope relationships for the terrainal areas are provided by detailed soil mapping conducted by the U. S. Department of Agriculture, Soil Conservation Service. The two principal soil associations within the schist terrain are the Chester-Elioak-Glenelg association and the Glenelg-Manor association. The Chester and Elioak silt loams are well-drained soils and occur on nearly level to moderately sloping surfaces. The Glenelg silt loam is moderately deep, well drained and generally occurs on moderate slopes. The topography of the Glenelg-Manor association is hilly and is characterized by long slopes and moderately broad ridges.


TERRAINAL UNITS
RELATIVE TO WASTE WATER APPLICATION,
CODORUS CREEK DRAINAGE BASIN
1 0 1 2
MILES
TRIASSIC SANDSTONE - SHALE TERRAIN
MIXED BEDROCK TERRAIN
YORK
CONESTOGA LIMESTONE TERRAIN
MIXED BEDROCK TERRAIN
PHYLLITE TERRAIN
MIXED BEDROCK TERRAIN
RED LION
SPRING GROVE
MIXED BEDROCK TERRAIN
PHYLLITE TERRAIN
MIXED BEDROCK TERRAIN
SCHIST TERRAIN
HANOVER
CONESTOGA LIMESTONE TERRAIN
PHYLLITE TERRAIN
(MARBURG SCHIST)
(WISSAHICKON SCHIST)
GLEN ROCK
SCHIST TERRAIN
SCHIST TERRAIN
SHREWSBURY
RAILROAD
NEW FREEDOM

Soils within the schist terrain can be grouped into three broad slope categories for each of the two associations; (a) 0-8 percent slope range; (b) the 8-15 percent slope range, and (c) in excess of 15 percent slope.

Grouping of soil mapping units according to these soil-slope categories provides a basis for determining the areal distribution of soil conditions most suited to land application of wastewater and of the dimension of potential application areas as determined by topographic conditions. Most suitable are the areas of deep well drained soils (Chester and Elioak) on slopes not exceeding 8 percent (A category). Soils occurring on slopes of 8 to 15 percent (B category) are likely to have greater limitations and those areas where slopes in excess of 15 percent exist (C category) are severely limited by slope and erosion factors. In addition, land areas occurring in the bottomlands of the narrow drainage valleys should be excluded from consideration because of the restricted areal extent and because of the liklihood for shallow depth to groundwater saturation. Soil texture and slope conditions most suited for land application are widespread within the Schist Terrain but the lateral extent of these areas is more restricted than in other terrainal areas because of the relatively deep dissection of this high lying region.

Phyllite Terrain - The Phyllite Terrain lies between the Martic Overthrust on the southeast and the Stoner Overthrust on the northwest. Included with the Harpers Phyllite which is the predominant bedrock are the Chickies Slate and the Antietam Quartzite. On the basis of specific capacity data, productivity of bedrock wells appear to be lower in this terrain than in the Schist Terrain which could require closer spacing of drainage control facilties.

Soil-slope relationships within the Phyllite terrainal area are similar to those described for the Schist Terrain Topographically, the Phyllite Terrain is less rugged than the adjacent Schist Terrain. Consequently, the ridge areas are somewhat broader and more gently sloping and the extent of contiguous area of most satisfactory slope conditions are likely to be greater in extent.

Conestoga Limestone Terrain - The Conestoga Limestone Terrain occurs as a relatively narrow, discontinuous unit within the Hanover-York Valley. The topography is gently to moderately sloping topography.

The principal soil association within the Conestoga limestone terrain is the Conestoga-Duffield-Bedford-Lawrence association. Of these soils, the Conestoga silt loam is the most extensive soil in the terrain. The Conestoga silt loam is a deep well-drained soil formed on shaly limestone or calcareous schist. Slopes range from nearly level to moderately steep but the gentler slopes predominate. The subsoil has a well developed B zone of silty clay which forms a restriction to the downward movement of water. The tight, fine-grained subsoil is a primary deterent to the use of this terrainal unit for wastewater application. Soil thickness over the limestone is variable ranging from 8 to more than 40 feet and averaging about 20 feet. Wide variation in depth of weathering is typical of carbonate (limestone and dolomite) terrains.

At Hanover, the Conestoga Terrain is a broad gently sloping low-lying area of relatively slight relief. Groundwater is encountered at relatively shallow depth (generally less than 15 feet below land surface) and groundwater gradients are generally low. At other locations within the Hanover-York Valley, such as near Bair, the Conestoga limestone is situated at an intermediate topographic level between the floodplain and the uplands. There the depth to groundwater is greater, groundwater gradients are larger and groundwater movement is likely to be directed to discharge points in the bottomlands.

Specific capacities of water wells in Conestoga bedrock ranging from 0.05 to more than 13 gpm per ft. drawdown. At Hanover, available specific capacity data on three wells indicate specific capacities consistently less than 1.0 gpm per ft. drawdown and well yields of less than 100 gpm.

Triassic Sandstone-Shale Terrain - Only a small portion of the northern part of the Codorus Creek Basin lies within the Triassic Sandstone-Shale Terrain. The geologic units contained in this area belong to the New Oxford Formation. The topography is nearly level to gently sloping and is a part of the area known locally as the Dover Plains.

Soils in this area belong to the Penn-Lansdale-Readington association. They are generally shallow to moderately deep with interbedded sandstone and shale bedrock at generally less than 3 feet. Individual beds of

shale or sandstone range from less than 10 feet to more than 50 feet in thickness and thinner units are predominant. The rocks dip to the northwest and textural changes from sandstone to shale bedrock within short leateral distances are common.

Mixed Bedrock Terrain - The remainder of the basin consists of a complex of limestone, dolomite, shale, slate, phyllite and quartzite of Cambrian age. Extensive folding and faulting of these units has produced an area of great lithologic variety. Uniformity of bedrock conditions over any area of significant extent is unlikely. Information to establish nature and extent of individual textural elements within this area is not available and comprehensive and detailed geologic surveys and analysis would be required to establish the textural and structural relationships.

The Mixed Bedrock Terrain contains a variety of soils related primarily to the Cardiff-Whiteford, Hagerstown, Duffield and Glenelg-Manor associations. These soils have a wide range of textural, profile and slope conditions which vary within relatively short lateral distances.

The water-yielding characteristics of the bedrock also vary widely owing to the complex distribution of lithologies. The predominant lithologies within the terrain are limestone and dolomite which characteristically display broad ranges in soil texture, soil thickness and permeability conditions.

Slope conditions also vary widely within the terrain ranging from areas of nearly level or gently sloping topography to excessively steep slopes. On the more soluble bedrock units, a karst topography containing many sinkholes has developed.

Relative Suitability of Terrainal Units for Wastewater Application

Terrainal Units Most Suited for Land Application - The Schist Terrain and the Phyllite Terrain present the best opportunities for wastewater application from the standpoint of requisite physical characteristics. These two terrains constitute the bulk of the area of the basin southeast of the Hanover-York Valley physiographic unit.

Soil profile characteristics of the Chester-Elioak-Glenelg and the Glenelg-Manor associations within the Schist Terrain as displayed by the site area investigations at Glen Rock indicate less intense development of the B-zone in terms of clay content and thickness than in the other terrainal units within the basin. Average permeability levels of

about 0.5 feet per day are, however, indicative of the need for the careful adjustment of application procedures to prevent ponding.

The principal advantage of the Schist Terrain is in the somewhat higher potential transmissivity of the weathered and unweathered schist especially in the area of the Wissahickon formation. Specific capacity data from wells in this unit indicates that somewhat better opportunities for drainage control by use of wells and interceptor ditches and tiles are likely to exist in this unit as compared to other terrainal areas within the basin.

The Phyllite Terrain including the Harpers Phyllite and Chickies Slate geologic units is somewhat less favorable than the Schist Terrain from the standpoint of soil permeability and drainage control requirements but is somewhat more favorable from the standpoint of topography. Investigations in the Phyllite terrain southeast of Spring Grove indicated thicker development of the B-horizon of the soil profile with slightly lower permeability values. In addition, wells in the phyllite have a lower average specific capacity than do water wells in the Schist Terrain.

Terrainal Units Least Suited for Land Application - The terrainal areas least suited for land application of wastewater in the Codorus Creek Basin are the Conestoga Limestone Terrain, the Mixed Bedrock Terrain and the Triassic Sandstone-Shale Terrain.

The principal limitations of the Conestoga Limestone Terrain is the tight subsoil produced by weathering process and the generally high water table conditions at Hanover. In addition, the presence of solution channels in the underlying bedrock and the variable depth to bedrock indicate that groundwater quality control is likely to be difficult.

In the Mixed Bedrock Terrain, the rapid and unpredictable changes in lithologic character of the bedrock make identification and analysis of land tracts of any significant extent unreliable. The most suitable areas topographically for land application are those parts of the terrain underlain by limestone and dolomite bedrock. These regions have restrictions similar to those in the Conestoga limestone terrain.

The Triassic Sandstone-Shale Terrain is limited in its utility for wastewater application because of the shallow depth to unweathered bedrock (generally less than 3 feet) and due to the stratified nature of the relatively thin beds of sandstone and shale. The stratified nature of the lithologic units results in pronounced changes in texture within short lateral distances and marked changes in texture with depths which interrupt and otherwise disturb subsurface flow patterns.

IV. FACILITIES REQUIREMENTS - EXISTING PROGRAMS

<u>Treatment Performance and Capacities of Existing Systems</u>

All existing municipal wastewater treatment facilities in the study area provide essentially a secondary treatment level of performance. The combined capacity of all present plants is 33 MGD whereas present average flows total 24 MGD. The York STP service area is the only one where flows presently exceed treatment capacity.

To meet the present Commonwealth of Pennsylvania effluent restriction requires improvements in biological removal performance by the York, Spring Grove, Penn Township and Red Lion treatment plants. Also, none of the treatment plants in the study area have facilities in place for removal of phosphorus.

Increased flows projected through the year 1985 will also require expansion of plant capacities. A total of 8.4 MGD of additional study area treatment capacity will be needed. Table III-10 shows these capacity needs.

Two new secondary treatment plants incorporating polishing lagoons for additional BOD removal are presently in the final design or construction stage. These plants will serve the Dover Township-suburban York area, and the upper basin satellite community area encompassing Railroad, New Freedom and Shrewsbury. These plants will have a total combined capacity of 2.1 MGD. Neither of these two have provided phosphorus removal capability at the present time.

<u>Present Cost of Waste Treatment</u> - Table III-11 which lists the remaining capital debt and annual operating costs for each treatment system (treatment plant and major interceptors), shows that the total annual cost for all municipal facilities is presently $1,487,000. This is based on 30 year amortization of the present $5,486,000 outstanding debt plus the annual operating costs. The total annual cost is equivalent to $13.00 per capita for the present 114,000 residents served by these systems. The P. H. Glatfelter Co. contributes an additional $742,000 annual cost producing a study area annual total cost of at least $2,229,000 (certain minor public and industrial treatment costs have not been included). Debt retirement associated with local collection systems is also not included in these figures.

TABLE III-10

CODORUS BASIN STUDY AREA
TREATMENT FACILITY CAPACITY NEEDS
1972 - 2000

Municipal Facility	Present Capacity	Projected Flows 1985	Projected Flows 2000	Additional Capacity Needs Thru 1985	Additional Capacity Needs Thru 2000
York	18.0	24.7	36.0	6.7	18.0
Springettsbury	8.0	7.1	9.8	No Additions	1.8
Dover Borough	0.25	To Dover Twp.		Abandon	
Dover Township	1.75	1.3	2.8	No Additions	1.05
Red Lion	0.7	1.9	2.7	1.2	2.0
Spring Grove	0.25	0.25	0.3	No Additions	0.05
Penn Township	1.75	1.6	2.2	No Additions	0.45
Hanover	2.5	3.0	3.9	0.5	1.4
Shrewsbury-Railroad New Freedom	1.35	1.15	1.9	No Additions	0.55
Glen Rock	0.3	0.3	0.5	No Additions	0.2

TABLE III-11

PRESENT COSTS OF WASTEWATER TREATMENT IN STUDY AREA

Treatment System	Unretired Debt: Treatment Facilities	Unretired Debt: Collection Facilities	Unretired Debt: Total	Annual Capital(1) Cost	Operating & Maintenance Costs	Total Annual Cost
York	1,444,000	-	1,444,000	103,000	800,000	903,000
Springettsbury	780,000	780,000	1,560,000	108,000	68,000	176,000
Red Lion	NA	NA	265,000	19,000	40,000[a]	59,000
Dover	NA	NA	NA	-	15,000[a]	15,000
Glen Rock	NA	NA	500,000	36,000	22,000	58,000
Spring Grove	NA	NA	NA	-	15,000[a]	15,000
Penn Township	450,000	840,000	1,290,000	94,000	64,000	158,000
Hanover	NA	NA	527,000	38,000	65,000	103,000
Total Municipal			5,586,000	$398,000	$1,089,000	$ 1,487,000
P. H. Glatfelter Co.	1,950,000		1,950,000	142,000	600,000	742,000
COMBINED TOTAL			7,536,000	$540,000	$1,689,000	$ 2,229,000

NA = Not available
a = Estimated
(1) = Based on 6% interest and 30-year bonding

Facilities Improvement Programs

Performance requirements and timetables established to satisfy the water quality improvement program of the Commonwealth of Pennsylvania have produced an extensive planning and facilities design effort in the study area.

The status of the significant activities under way are identified below:

Shrewsbury-Railroad-New Freedom Sewerage System - A sewage collection, interceptor and treatment facility is under construction. The treatment plant is a 1.35 MGD facility incorporating contact stabilization, secondary biological treatment, a polishing lagoon for improved BOD reduction, chlorination and reaeration. Discharge will be to the South Branch of Codorus Creek.

Dover Township Sewerage System- Sewage collection, interceptor and treatment facilities have been designed for the urbanized portions of Dover and West Manchester Townships. The treatment system is similar to that of the Shrewsbury, Railroad, New Freedom area and is designed for a capacity of 1.75 MGD. Discharge will be to Conewago Creek.

Mill Creek Interceptor - Planning and design studies are under way for the construction of an interceptor up Mill Creek to Red Lion. Negotiations are under way to include the Borough of Red Lion and thereby permit abandonment of the present Red Lion treatment plant. Wastes collected by this interceptor would be treated at the Springettsbury treatment plant.

York STP Expansion and Up-Grading - Advanced planning and design studies are under way to expeand the capacity of the York secondary treatment plant by 8 MGD. Preliminary planning studies are also under way for advanced treatment facilities required to meet Commonwealth of Pennyslvania discharge restrictions.

Spring Grove STP Improvements- Planning studies are under way for facilities to provide increased treatment performance.

Red Lion STP Improvements - Studies under way to evaluate whether to up-grade at local plant or abandon plant and connect to Springettsbury treatment plant.

Penn Township STP Improvements - Planning studies under way to select facilites for BOD reduction & phosphorus control.

As a basis for evaluating new facilities requirements and costs, the following of the investments indicated in Table III-12 are assumed as having been implemented and in place.

Shrewsbury, Railroad, New Freedom treatment and interceptor facilities

Dover Township treatment and interceptor facilities

Mill Creek interceptor

These facilities are incorporated as being completed in the alternatives evaluation. After completion of these facilities it is also assumed, for planning purposes, that the existing Red Lion and Dover Borough treatment plants would be abandoned.

V. WASTEWATER ALTERNATIVES EVALUATION

Analysis and identification of wastewater management alternatives for the Codorus Basin requires joint recognition of a number of management factors. These include:

1. Anticipated long range water quality management criteria more restrictive than the present regulatory requirements.

2. The impact effects of Codorus Basin discharges on the Susquehanna River.

3. The problem of low flow conditions and resultant minimal natural dilution potential.

4. The long range future problem of limited water supplies within the Basin.

5. Area-wide existing institutional patterns and uncertain opportunities for change.

6. Courses of action presently considered viable on the local, state and federal level.

Conceptual Displays

The initial group of alternatives formulated reflected the charge on the consultant to present a full range of relevant technological performance and institutional choices to the policy committee for review. A group of 8 basic management strategies were reflected in the set of 10 alternatives presented initially. These strategies include:

1. Diversion of wastes out of Basin.

2. Importation of Susquehanna River water for dilution of waste flows.

3. Complete regionalization of all waste treatment.

4. Abandonment of biological treatment processes in favor of chemical/physical treatment systems.

5. Independent upgrading of existing local community treatment systems.

6. Use of land irrigation for final treatment of all waste.

7. Use of land irrigation for final treatment of upper basin small communitites. York area wastes provided advanced water process treatment.

8. Reuse of treatment plant effluent as process water supply for P. H. Glatfelter Company.

The 10 individual conceptual displays are listed below:

1. Water Importation - Importation of large volumes of water from the Susquehanna to the upper Codorus Basin to substantially dilute wastes discharged.

2. Sub-centralized Advanced Treatment - The present local secondary treatment plants would be retained for pretreatment. Advanced tertiary plants would be constructed at each major urban center to receive waste from a number of local secondary plants.

3. Decentralized Advanced Treatment - Evaluation of the cost and performance capabilities of maintaining the present institutional and systems development pattern in light of anticipated long range water quality requirements.

4. Centralized Advanced Treatment - Construction of one central treatment facility for advanced waste treatment. This plant located at York would receive secondary treated wastes from the York area and upper West Branch communities. The South and East Branch upper basin communities would discharge raw waste into the Springettsbury treatment plant via the new Mill Creek interceptor.

5. Centralized Physical-Chemical - All existing investments in biological treatment facilities would be abandoned in favor of a single physical-chemical treatment plant.

6. Sub-centralized Physical-Chemical - Upper basin present treatment plants would be abandoned in favor of a single physical-chemical facility located above York. York area treatment plants would be retained in conjunction with an advanced biological treatment plant to serve the entire York urban area.

7. Out of Basin Diversion - All wastes would receive secondary treatment and phosphorus removal at one of 5 plants (York, Springettsbury, Penn Township, Hanover, Spring Grove) and then be discharged to the Susquehanna River via a pipeline.

8. All Land Disposal - Land treatment sites would be developed to give final tertiary treatment to all basin wastes. Initial treatment through the secondary level would be provided by existing secondary treatment plants or by aerated lagoon treatment cells.

9. Land-Water Combination - Land Treatment sites would be developed only for the upper basin communities. A regional advanced waste treatment plant would be constructed for the York area which would receive secondary effluent from the York and Springettsbury plants.

10. Reuse - The potential for the use of the secondary effluent from the York area treatment plants as raw process water supply for the P. H. Glatfelter Company paper mill is evaluated. Excess flows would receive land treatment in advanced water process treatment. Land treatment of Glatfelter wastes tor color removal after secondary treatment is also considered.

Specific aspects of each of these 10 alternatives are presented in Table III - 14. Factors that influenced design configuration of individual alternatives included:

1. The expected construction of the Mill Creek interceptor and resultant requirement for only the acceptance of raw wastes.

2. At the time of the initial formulation, the Dover Township and Shrewsbury-New Freedom-Railroad area treatment plants were not believed to be as far along in implementation as was later apparent. They were not taken as in-place investments.

Review of these intitial alternatives by the Policy Committee was largely directed at the performance and institutional dimensions. Costs were received as being too preliminary to be a basis of initial selection.

TABLE III-14

DESIGN AND PERFORMANCE ASPECTS OF INITIAL ALTERNATIVES

	Alternative	Design and Performance Aspects
1.	Water Importation	- Increases basin flows substantially - Reduced treatment performance based on dilution concept - Does not reduce total loads on Susquehanna
2.	Sub-centralized Advanced Treatment	- Retains flows at points of origin - Has some operating savings due to AWT sub-regionalization - Reduction in transmission facilities compared to complete regionalization
3.	Decentralized Advanced Treatment	- Minimum change in present institutional arrangements - High study area operating costs - Difficult problem of performance consistency
4.	Centralized Advanced Treatment	- Major investment in conveyance pipelines and pumping facilities - Efficient operating scale for treatment - Problem of flow diversion from upper basin
5.	Centralized Physical-Chemical	- Explores cost/performance implications of abondoning present biological treatment facilities
6.	Sub-centralized Physical-Chemical	- Existing major treatment plants would be kept - Only two independent treatment systems would exist - *Physical-Chemical* plant would discharge above York
7.	Out-of-Basin Diversion	- Reduced level of treatment provided - All in-basin discharge eliminated - Problem of natural flow reduction
8.	All Land Disposal	- Total area required is 17,000 acres with Glatfelter included and 13,000 acres without Glatfelter - Highest level of treatment performance of all alternatives - Returns flow to upper basin
9.	Land-Water Combination	- Accomplishes high land treatment performance in upper basin - Reduces land site acquisition
10.	Reuse	- Provides for the saving of up to 28 MGD in local water resources - Reduces total amount of waste to be treated by up to 28 MGD - Provides for municipal nutrient use synergistic benefits at P. H. Glatfelter Co.

A Policy Committee consensus developed around the further exploration and refinement of a group of 5 alternatives based on a consolidation of the initial 10. These five were to take the following form:

1. A regional collection system to eliminate the discharge of wastes in the upper basin. Final discharge to the Codorus at or below York and to the Susquehanna River was to be evaluated with respect to the level of treatment required, costs and environmental performance.

2. Treatment at selected local municipal facilities to a range of performance levels (Treatment types A, B, C, and D as identified in Table III - 7) with discharge locally.

3. Continued exploration and refinement of the all land treatment system (municipal and Glatfelter paper mill wastes). Geological and site evaluation studies were not completed at the time of the formulation of the initial 10 alternatives.

4. Land treatment of upstream communities and advanced water process treatment of York area wastes.

5. Reuse of York secondary effluent as process water supply for the P. H. Glatfelter paper mill.

Alternatives Refinement

Refinements in flow projections, capital and operating cost bases and design aspects of facilities were made in conjunction with re-definition of individual alternatives. The revised group of alternatives are detailed below.

Alternative 1

Alternative 1 is composed of two basic management strategies (1a and 1b).

Alternative 1a - Regional collection pipelines with discharge to Susquehanna River. A range of configurations for this basic alternative are considered which include:

Option 1. Treatment at local plants to secondary treatment level with 80 per cent phosphorus removal. A transmission system would collect all treated wastes and discharge to the Susquehanna River. The Glatfelter paper mill would receive secondary treatment at its own facility with effluent discharged to the transmission pipeline.

Option 2. Sub-regional new treatment facility in West Branch at Spring Grove. All other domestic flows treated at York or Springettsbury. All municipal plants would provide secondary treatment and 80 per cent phosphorus removal. Glatfelter wastes would receive secondary treatment at present facility and be discharged to pipeline.

Option 3. This option explores the economics of utilizing the nutrient deficiency of the Glatfelter waste to accomplish phosphorus removal and some ammonia removal for the municipal wastes produced in the West Branch above the paper mill. The present treatment plants at Hanover, Penn Township and Spring Grove would give primary treatment and chlorination to their wastes which would then be piped to the Glatfelter secondary biological facility. The combined effluent from the Glatfelter secondary would be discharged to the Susquehanna River pipeline. All other basin wastes would be handled as in Option 2.

Alternative 1b - Regional facility or facilities for treatment of municipal wastes with discharge to Codorus Creek below York. Alternative levels of treatment considered include Treatment type B, C, D and E (see Table III - 7).

Glatfelter wastes provided with advanced waste treatment for color removal and discharged to Codorus Creek above Indian Rock Dam. A total of 10 configuration and treatment options are evaluated which encompass municipal treatment type B, C, D and E.

Option 1. Secondary treatment and 80 per cent phosphorus removal provided for all municipal wastes at York and Springettsbury plant. Advanced treatment provided at central facility located near York STP.

	Initially only treatment type B would be provided.
Option 2.	Secondary treatment and 80 per cent phosphorus removal provided for municipal wastes at York and Springettsbury plants. Advanced treatment provided at York and Springettsbury plants. Initially only treatment type B would be provided.
Option 3.	Secondary treatment with 80 per cent phosphorus removal provided at all existing treatment plants. Advanced treatment provided at central facility located near York STP. Initially only treatment type B would be provided.
Options 4, 5, 6.	Correspond to Options 1, 2 and 3, respectively, in terms of configuration. However, options 4, 5 and 6 encompass municipal treatment type C (secondary treatment, 98 per cent phosphorus removal, nitrification/denitrification, filtration, reaeration and chlorination).
Options 7, 8, 9.	Correspond to Options 1, 2 and 3, respectively, in terms of configuration. However, Options 7, 8 and 9 encompass municipal treatment type D (secondary treatment, 98 per cent phosphorus removal, nitrification/denitrification, filtration, reaeration and chlorination).
Option 10.	Municipal treatment type E - Abandonment of all existing treatment plants. Replacement with a single regional physical/chemical treatment facility (lime precipitation, carbon adsorption and ion exchange for ammonia removal).

Alternative 2

Treatment at local municipal facilities to a range of performance levels (Types B, C and D) with discharge locally. Three options are:

Option 1.	Type B Treatment
Option 2.	Type C Treatment
Option 3.	Type D Treatment

Alternative 3

Land irrigation of all municipal and Glatfelter wastes. Secondary treatment is provided all wastes utilizing existing treatment facilities in the major urban areas and new aerated lagoon facilities for the smaller sub-urban nodes.

On the basis of a 2" per week application rate for an 8-month annual irrigation period for municipal wastes and 3" per week for the nutrient deficient Glatfelter waste, land area requirements for each of the major flow sources is shown below:

Site Requirements-Acres

	1985		2000	
	Net Irrigation Area	Total Site Area	Net	Total
York Urban Area	7,060	10,600	9,950	14,950
Upper Basin Communities	1,300	2,750	1,820	3,850
P. H. Glatfelter Co.	3,120	4,700	3,620	5,430

Alternative 4

Land irrigation of upstream communities, York and Springettsbury service area wastes provided Class C treatment and discharged to Codorus Creek. Glatfelter wastes provided advanced waste treatment for color removal and discharged into the West Branch.

Alternative 5

The focus of this alternative is the potential to reuse York secondary effluent as process water supply for the P. H. Glatfelter paper mill. Two basic variants (options) are considered and identified as 5a and 5b.

<u>Alternative 5a</u> evaluates advanced water process treatment of the reused effluent from the paper mill. A carbon adsorption system for color removal and reaeration for thermal reduction and oxygen enhancement is provided.

<u>Alternative 5b</u> considers land irrigation of the Glatfelter wastes after secondary treatment.

In both 5a and 5b wastes from the upstream communities are land irrigated and advanced water process treatment is provided for Springettsbury service area wastes.

TABLE III-15

CAPITAL OF OPERATING COSTS

OF REVISED ALTERNATIVES

	Total Capital Investment 1973-2000	Average Annual Cost	Average Annual Operating Costs
Alternative I			
Ia			
Option 1	$50,961,000	$8,005,000	$4,853,000
2	49,888,000	7,748,000	4,542,000
3	52,489,000	7,623,000	4,380,000
Ib			
Option 1	49,185,000	8,347,000	5,234,000
2	50,452,000	8,579,000	5,378,000
3	51,875,000	8,944,000	5,784,000
4	57,622,000	9,469,000	5,848,000
5	59,756,000	9,687,000	5,949,000
6	60,749,000	10,026,000	6,361,000
7	66,337,000	10,450,000	6,353,000
8	71,708,000	10,901,000	6,485,000
9	71,817,000	11,112,000	6,836,000
10	56,302,000	9,803,000	6,213,000
Alternative II			
Option 1	41,957,000	8,298,000	5,886,000
2	53,872,000	9,829,000	6,755,000
3	67,715,000	11,458,000	7,626,000

TABLE III-15 (cont.)

	Total Capital Investment 1973-2000	Average Annual Cost	Average Annual Operating Costs
Alternative III	$103,020,000	$14,897,000	$4,042,000
Alternative IV			
(water)	38,428,000	7,603,000	5,315,000
(land)	17,358,000	2,075,000	1,025,000
(total)	55,786,000	9,678,000	6,340,000
Alternative V			
Va			
(water)	39,113,000	7,091,000	4,716,000
(land)	17,190,000	2,062,000	1,024,000
(total)	56,303,000	9,153,000	5,740,000
Vb			
(water)	25,581,000	3,461,000	1,953,000
(land)	50,333,000	8,776,000	5,343,000
(total)	75,914,000	12,237,000	7,296,000

Comparative Analysis of Performance

Capital and Operating Costs - Table III-16 summarizes the total capital investment and average annual costs for the least cost option of each configuration as presented with the revised set of alternatives for the different treatment types. The table is arranged to permit comparison of alternatives with similar levels of performance capability. Costs are shown to be not significantly different for regional vs. local systems at the lower level of performance capability (Type B). However, with increasing level of treatment the regional water process treatment system is significantly cheaper than the local dispersed system plan. At the highest level of treatment the reuse alternative is the least cost choice. The next lowest cost occurs with the combination land/water system (Alternative 4).

Stream Flow Effects - Estimates of minimum average monthly stream flows for each of the treatment alternatives at 6 critical locations in the Codorus Basin (located on Exhibit III-16) are compared to present flow levels in Table III-17. The following assessments are made:

1. Stream flow is indicated as being drastically reduced with Alternative 1a (Susquehanna River Diversion) in the West Branch and the Main Stem at and below York.

2. Return of Glatfelter wastes to the West Branch (all Alternatives except 1a) maintains present levels of flow through York.

3. Irrigation of York wastes in the upper basin (alternatives 3 and 5b) increases low flows substantially in the West Branch and the main stem through York.

Water Quality Considerations - The pollutant removal performance of each of the alternatives with respect to phosphorus and nitrogen is summarized in Table III-18. This table shows that without extremely high ultimate levels of phosphorus removal (at least 98 per cent), total phosphorus discharge to the Susquehanna will return to former levels by the year 2000, with implementation of only the present 80 per cent reduction criteria.

The highest level of phosphorus removal performance is achieved with the all land treatment system due to its ability to reduce total phosphorus to 0.05 mg/l in the effluent. Other

TABLE III-16

COMPARISON OF ALTERNATIVE SYSTEM COSTS

FOR LEAST COST OPTION

Alternative		Total Capital Investment	Average Annual Cost 1973-2000
1a	Option 3	52,489,000	7,527,000
Type B Treatment			
1b	Option 1	49,185,000	8,279,000
2	Option 1	41,957,000	8,200,000
Type C Treatment			
1b	Option 4	57,622,000	9,351,000
2	Option 2	53,872,000	9,754,000
Type D, E or F Treatment			
1b	Option 7	66,337,000	10,351,000
1b	Option 10	56,302,000	9,814,000
2	Option 3	67,715,000	11,433,000
3		103,020,000	14,897,000
4		55,786,000	9,555,000
5	a	56,303,000	9,053,000

EXHIBIT III-15

CODORUS CREEK DRAINAGE BASIN
WATER QUALITY EVALUATION POINTS

A. WEST BRANCH ABOVE SPRING GROVE
B. WEST BRANCH BELOW GLATFELTER
C. SOUTH BRANCH
D. MAIN STEM ABOVE YORK STP
E. MILL CREEK
F. MAIN STEM BELOW YORK STP AND SPRINGETTSBURY STP
G. INCREMENTAL INCREASE IN SUSQUEHANNA FROM CODORUS CREEK

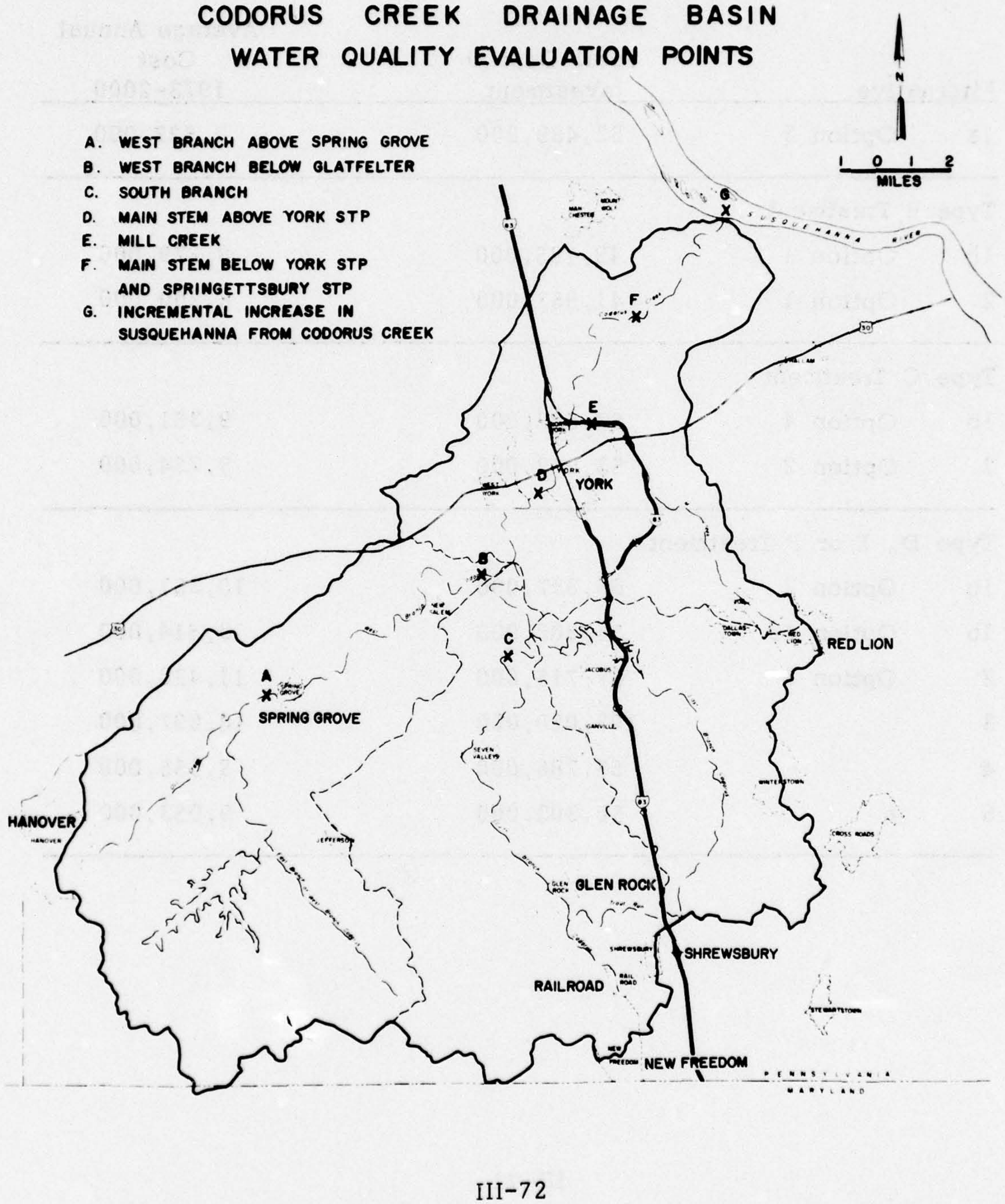


TABLE III-17
HYDRAULIC FLOWS AT CRITICAL POINTS
FOR TREATMENT ALTERNATIVES
(Minimum Average Monthly Flows in Mgd)

		A	B	C	D	E	F	G
Alternative 1a	1980	28	4.6	28	22	5.6	24	1,500
	2000	30	2.4	28	18	5.6	18	1,500
Alternative 1b	1980	28	28	28	45	5.6	85	1,500
			(23)		(23)		(60)	
	2000	30	30	28	46	5.6	109	1,500
			(28)		(28)		(91)	
Alternative 2	1980	29	29	30	49	7.2	82	1,500
		(1.4)	(24)	(2.0)	(26)	(1.6)	(58)	
	2000	33	33	31	52	8.3	105	1,500
		(2.2)	(30)	(3.6)	(34)	(2.7)	(87)	
Alternative 3	1980	31.7	52	40	80	5.6	83	1,500
		(4.1)	(47)	(12.15)	(59.25)		(59)	
	2000	36.5	70	46.4	104.1	5.6	106	1,500
		(6.1)	(67)	(18.8)	(88.5)		(88)	
Alternative 4	1980	32	32	30	48	5.6	83	1,500
		(4.1)	(27)	(2.0)	(29)		(59)	
	2000	37	37	31	50	5.6	106	1,500
		(6.1)	(34)	(3.6)	(38)		(88)	
Alternative 5a	1980	27	50	30	67	5.6	76	1,500
		(4.1)	(27)	(2.0)	(29)		(35)	
	2000	29	57	31	68	5.6	90	1,500
		(6.1)	(34)	(3.6)	(38)		(58)	
Alternative 5b	1980	27	50	30	67	5.6	76	1,500
		(4.1)	(27)	(2.0)	(29)		(35)	
	2000	29	68	31	78	5.6	90	1,500
		(6.1)	(45)	(3.6)	(48)		(58)	
Present Conditions (1970)	R*	24.1	24.1	29	45.7	6.0	75.8	1,500
		(1.0)	(18.3)	(0.2)	(19.5)	(0.4)	(41.0)	

* Based on 1927 to 1969 Records.
( ) Amount contributed by wastewater discharges

TABLE III-18

DISCHARGE TO SUSQUEHANNA RIVER
(lbs/day)

Alternative	Total Phosphorus	Total Nitrogen
Present Conditions	1,405	5,545
2000 Conditions		
Alternative 1a		
Options 1, 2	1,040	13,140
Option 3	1,040	10,563
Alternative 1b		
Options 1, 2, 3	1,040	13,140
Options 4, 5, 6	1,040	1,940
Options 7, 8, 9	148	1,940
Option 10	148	1,940
Alternative 2		
Option 1	1,040	13,140
Option 2	1,040	1,940
Option 3	148	1,940
Alternative 3	36	1,470
Alternative 4	890 (135)	1,940
Alternative 5a	390 (88)	1,470
Alternative 5b	185 (36)	1,000

NITROGEN DISCHARGE: Based on 2 mg/l total nitrogen discharge for all municipal treatment facilities and 4 mg/l for Glatfelter carbon adsorption final treatment system. All land treatment system discharge assumed to be 2 mg/l.

PHOSPHORUS DISCHARGE: Assumed to be 2 mg/l for 80 per cent removal treatment and 0.2 mg/l for 98 per cent removal; land system effluent assumed to be 0.05 mg/l. Glatfelter discharge concentrations taken as 0.2 mg/l.

( ) increased treatment to 98 per cent removal of phosphorus.

alternatives are also capable of maintaining phosphorus discharge at very low levels. The numbers in parentheses for Alternatives 4, 5a and 5b are the discharge concentrations if the York area treatment plants increased phosphorus removal performance to the 98 per cent level instead of the 80 per cent level that was evaluated.

Nitrogen discharges are shown to be relatively similar for all of the alternatives. However, the least amount is contributed with Alternative 5b in which the York secondary effluent is reused and the Glatfelter effluent is irrigated. The nitrogen present in the York effluent would replace that which is provided as supplemental feed by Glatfelter in the activated sludge process.

Of concern on nitrogen discharge is the ability of the processes considered to maintain consistency in removal. Since the biological water based nitrification/denitrification process must operate in the winter it is subject to reduced efficiencies. It also is prone to performance reduction from upsets that carry through the secondary treatment plant.

The land treatment system in comparison does not require winter operation and is much less sensitive to upsets in performance. This is attributed to the dilution potential of the storage ponds and the stability of the processes accomplished in the soil environment.

<u>Selection of Final Alternatives</u> - Policy Committee review of the revised group of alternatives produced the early elimination of Alternative 1a as it did not adequately protect the Susquehanna River from degradation. Dilution as a major solution was not acceptable.

The Policy Committee in its early review generally regarded the all land treatment system as unfeasible due to the magnitude of land area required and its high estimated investment cost. In the course of further evaluation opportunities have been defined which could offset these concerns through the achievement of multi-purpose use of land site areas. Specifically, such opportunities include the possible linkages of a land site to water reuse at the P. H. Glatfelter Company paper mill, the use of storage ponds for thermal cooling activities and the achievement of metropolitan open space objectives.

The Citizens Advisory Committee, after review of the range of cost, performance and institutional aspects of the various alternatives, requested additional information on the costs to the local area of a range of treatment performance capability that could be selected for initial implementation. This analysis was to be performed on the alternatives selected for final consideration.

The policy committee directed the consultant to further explore 4 of the original 5 alternatives for identification of optimum design aspects which would facilitate the selection of alternative levels of initial performance. In this final analysis the existing facilities and other facilities approaching the construction stage (such as Dover and Shrewsbury-New Freedom-Railroad treatment plants) were to be utilized to the extent possible. Alternatives to be considered were:

Alternative I - Sub-centralized Advanced Waste Treatment

Alternative II - Local Community Individual Plant Upgrading

Alternative IV - Combination Land/Water Treatment

Alternative V - Reuse with Land Irrigation

Cost Analysis of Increased Performance

For these four alternatives a cost assessment was made of the implications of two staging schedules (options) for performance upgrading.

Option I provides only filtration, chlorination and reaeration in the 1973-80 period with nitrification/denitrification added in 1980 and facilities for increased (98 per cent) phosphorus removal provided in 1990.

Option II provides nitrification/denitrification, filtration, chlorination and reaeration initially in 1973 and increased phosphorus removal (98 per cent) in 1980.

Table III-19 summarizes the results of this analysis. The local costs per capita are shown to be only modestly higher for the higher performance option. The potential areawide savings in treatment costs with the Reuse Alternative are also evident.

With consideration of the comparison of costs for different levels of performance and the local objectives for environmental management, the Citizens Advisory Committee requested that the highest level of treatment capability be programmed for the Basin.

The following section evaluates the set of four final alternatives and updates costs to February 1972 levels. Other cost adjustments are also included to reflect design refinement of transmission and treatment facilities. These adjustments are based on extensive review of design-performance relationships, performance impact of peak flow conditions, process recirculation factors and the most recent data on the actual costs of advanced treatment facilities at the plant scale size.

The two capital cost curves shown by Exhibit III-12 reflect the changes in unit-capacity costs resulting from the refinement in design basis and updated cost information.

TABLE III-19

COST ANALYSIS OF OPTIONAL PERFORMANCE PHASING

		Alternative I	Alternative II	Alternative IV	Alternative V
Total Capital Investment 1973-2000	Option I	40,433,000	48,161,000	48,730,000	47,791,000
	Option II	43,646,000	51,450,000	50,597,000	49,039,000
Average Annual Operating Cost 1973-2000	Option I	3,900,000	4,199,000	3,788,000	3,136,000
	Option II	4,508,000	5,131,000	4,270,000	3,290,000
Average Annual Local Costs PER CAPITA 1973-2000	Option I	22.48	23.93	22.66	20.71
	Option II	25.10	27.18	24.43	21.03

VI. ANALYSIS OF MOST PROMISING ALTERNATIVES

From the group of ten initially defined wastewater management alternatives, four were identified through preliminary and secondary screening as being suitable for final consideration. The four selected for final evaluation are:

Alt. #1 - <u>A sub-centralized advanced waste treatment facilities plan</u>. Advanced treatment (nitrification, denitrification, chemical treatment, filtration and reaeration) would be provided at a central facility for each of three principal urbanized areas. Secondary treatment would be provided by the individual local communities at the existing plants.

Alt. #2 - <u>A local community facilities upgrading plan</u>. Advanced waste treatment for nitrogen, phosphorus, increased BOD and suspended solids removal would be provided at individual local treatment plants following the existing patterns of service area identification.

Alt. #4 - <u>A combination land/water process treatment plan</u>. Secondary treated wastes from the larger York urban area would be given advanced treatment at a central regional facility. Wastes from the upper basin urban areas would receive secondary treatment at present facilities and be pumped to land irrigation sites for final treatment. For areas without treatment facilities at the present time, an aerated lagoon secondary treatment system would be provided at the land irrigation site for pre-treatment.

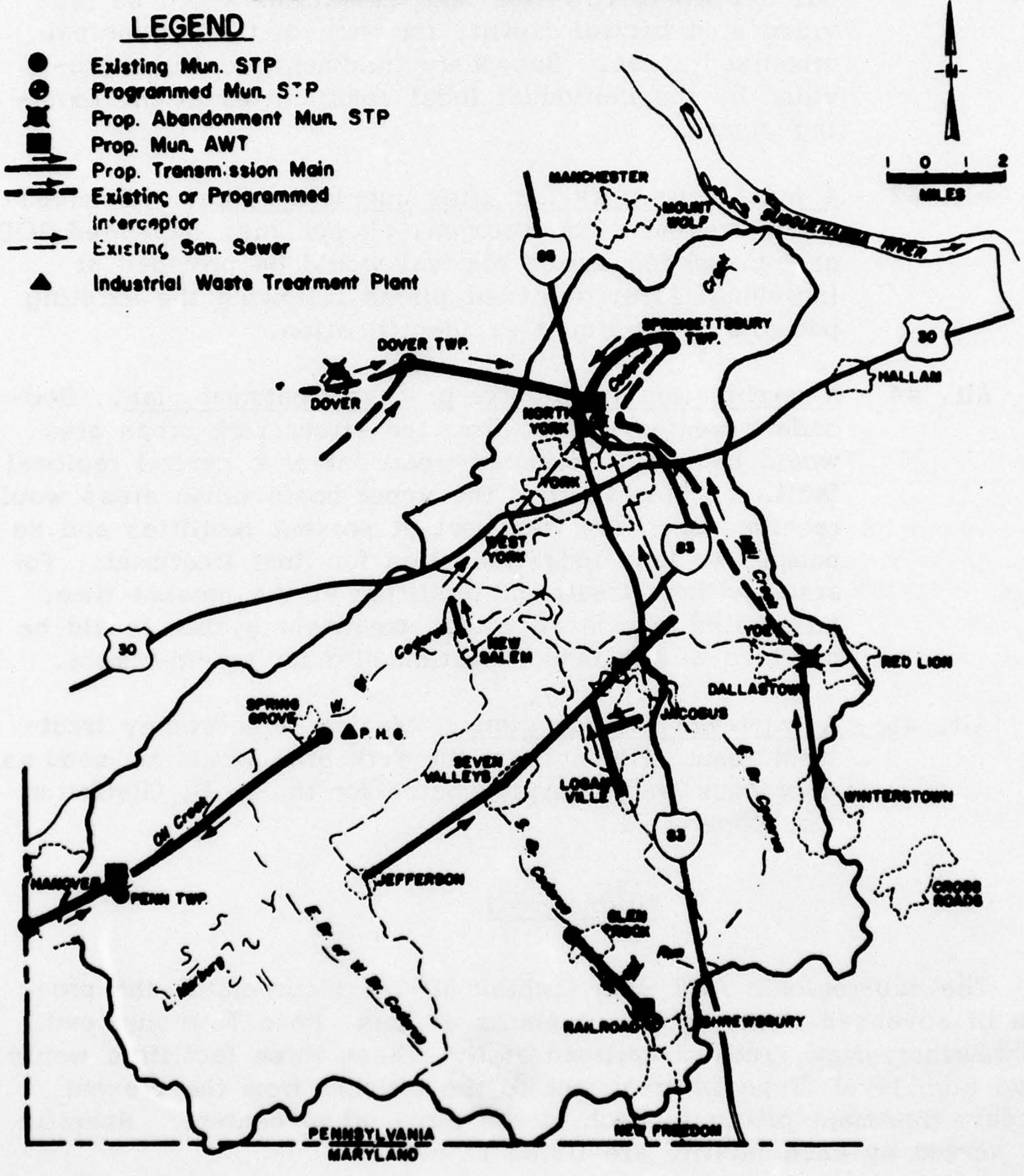
Alt. #5 - <u>A wastewater reuse plan.</u> Municipal secondary treatment plant effluent from the York area would be used as a process water supply source for the P. H. Glatfelter Co. paper mill.

Alternative I

The sub-regional AWT plan (Exhibit III-16) incorporates the provision of advanced waste treatment plants at York, Penn Township and the Shrewsbury-New Freedom-Railroad area. These three facilities would provide high level (Type D) treatment to the effluent from the present secondary treatment plants in each of the three urban centers. Specific areas served by each facility are listed below:

EXHIBIT III-16

CODORUS CREEK DRAINAGE BASIN
ALTERNATIVE I
SUB-REGIONAL WATER DISPOSAL



York AWT - York, Springettsbury and Dover Township plants and Jacobus, Loganville, Seven Valleys and Jefferson areas.

Penn Twp. AWT - Penn Twp, Hanover and Spring Grove plants.

Shrewsbury-New Freedom-Railroad AWT - Shrewsbury-New Freedom-Railroad and Glen Rock plants.

Facilities Requirements

A summary of AWT and local plant facilities requirements and expansions through the year 2000 is presented by Table III-20. A cost summary of sub-centralized AWT facilities is presented in Table III-21. Treatment facility construction is shown as occurring in two stages (1972-1985 and 1986-2000). Associated transmission pipeline and pumping facilities are listed in Table III-22.

The York area AWT regional plant would be adjacent to the York secondary treatment plant. This site is an efficient location for combined access from all three secondary plants. It also facilitates the provision of a pipeline to return the high quality effluent to a location above York for augmentation of low flow in Codorus Creek through the City of York. Augmentation would likely be a requirement of a program to revitalize the Creek in conjunction with the proposed downtown area renewal program.

The Hanover-Penn Township area AWT is located in the Codorus Basin to facilitate flow augmentation in future years as increased water supply diversions compound the late summer natural flow deficiencies.

Facilities Investments

Capital costs of treatment and transmission facilities to meet requirements through the year 2000 are summarized in Tables III-23 and 22 , respectively. These investments total to $31,574,000 during the 1972-85 first phase period and $25,145,000 during the 1986-2000 period.

Operating Costs

Estimated costs for local treatment, transmission and AWT operating expenditures during each phase of the 1972-2000 planning period are presented in Table III- 24. Total unit flow operating costs range between $255 and $700 per million gallons during the initial period at the three AWT plants with an average treatment cost equal to $292 per million gallons.

TABLE III-20

FACILITIES REQUIREMENTS FOR THE SUB-CENTRALIZED WATER PROCESS ALTERNATIVE

Service Area/ Treatment Plants	Present Capacity (MGD)	Treatment Plant Facilities (Added Capacity in MGD) 1972-85	1986-2000
YORK URBAN AREA			
Secondary Treatment Plants			
York	18.0	6.7	11.3
Springettsbury	8.0	1.0	3.5
Dover Twp.	1.75	No additions	1.0
Dover Borough	0.25	Abandon	
Red Lion	0.7	Abandon	
Regional AWT Plant	-	35.0	16.3
HANOVER-SPRING GROVE URBAN AREA			
Secondary Treatment Plants			
Hanover	2.5	0.5	0.9
Penn Twp.	1.75	No additions	0.45
Spring Grove	0.25	No additions	0.05
Regional AWT Plant	-	4.85	1.55
SHREWSBURY-NEW FREEDOM-RAILROAD AND GLEN ROCK URBAN AREA			
Secondary Treatment Plants			
Shrewsbury	1.35	No additions	0.55
Glen Rock	0.3	No additions	0.2
Regional AWT Plant	-	1.45	0.95

TABLE III-21

COST SUMMARY FOR THE SUB-CENTRALIZED AWT - WATER PROCESS ALTERNATIVE

	Cost ($) 1972-1985	Cost ($) 1986-2000
Capital Costs		
Transmission Facilities	6,029,000	-
Secondary Treatment	3,730,000	12,334,000
Advanced Treatment	21,815,000	12,811,000
Sub-Total	31,574,000	25,145,000
Contingencies (20%)	6,315,000	5,029,000
Sub-Total	37,889,000	30,174,000
Engineering (10%)	3,789,000	3,017,000
Total	41,678,000	33,191,000
Average Annual Operating & Maintenance Costs		
Transmission Facilities	54,000	96,000
Secondary Treatment	1,678,000	2,299,000
Advanced Treatment	1,990,000	2,791,000
TOTAL	3,722,000	5,186,000

TABLE III-22

CAPITAL COSTS OF INTERCEPTORS AND PIPELINES
FOR THE SUB-CENTRALIZED AWT - WATER PROCESS ALTERNATIVE

YORK URBAN AREA		
York STP - York AWT treated waste pipeline		
Pumping Station	600,000	
1,400 LF of 48" FM	109,000	
		709,000
Springettsbury to York treated waste pipeline		
Pumping Station	105,000	
21,500 LF of 36" FM	1,180,000	
		1,285,000
Dover-York treated waste pipeline		
Pumping Station	70,000	
27,500 LF of 18" FM	688,000	
		758,000
SHREWSBURY-NEW FREEDOM-RAILROAD AND GLEN ROCK URBAN AREA		
Glen Rock - Shrewsbury treated waste pipeline		
Pumping Station	55,000	
22,500 LF of 12" FM	338,000	
		393,000
Shrewsbury STP - Shrewsbury AWT		
Pumping Station	60,000	
		60,000
HANOVER-SPRING GROVE URBAN AREA		
Hanover-Penn Twp. treated waste pipeline		
Pumping Station	80,000	
18,250 LF of 20" FM	512,000	
		592,000
Penn Twp. STP - Penn Twp AWT	60,000	
		60,000
Spring Grove-Penn Twp treated waste pipeline		
Pumping Station	35,000	
33,000 LF of 10" FM	412,000	
		447,000
MAJOR AREAS SUBTOTAL		4,304,000

TABLE III-22 (Cont'd)

CAPITAL COSTS OF INTERCEPTORS AND PIPELINES
FOR THE SUB-CENTRALIZED AWT - WATER PROCESS ALTERNATIVE

Small Urban Area Facilities		
Jefferson - Seven Valleys interceptor		
25,200 LF of 8" GR	352,000	
		352,000
Seven Valleys - Reynolds Mill interceptor		
27,300 LF of 8" GR	382,000	
		382,000
Reynolds Mill - Spry interceptor		
Pumping Station (2 Stage Sta)	100,000	
14,000 LF of 12" FM	210,000	
3,100 LF of 10" GR	54,000	
		364,000
Loganville & Jacobus - Reynolds Mill interceptor		
7,100 LF of 8" GR	100,000	
9,700 LF of 8" & 10" GR	155,000	
3,200 LF of 8" GR	45,000	
		300,000
New Salem - York interceptor		
Pumping Station	30,000	
9,400 LF of 6" FM	82,000	
1,200 LF of 8" GR	17,000	
		129,000
Winterstown - Red Lion interceptor		
Pumping Station	30,000	
22,400 LF of 6" FM	168,000	
		198,000
Small Urban Area Subtotal		1,725,000
TOTAL CAPITAL COST OF ALL TRANSMISSION FACILITIES		6,029,000

TABLE III-23

CAPITAL COSTS FOR THE SUB-CENTRALIZED AWT - WATER PROCESS ALTERNATIVE

Service Area/ Treatment Plants	Treatment Plant Capital Costs ($) 1972-1985	1986-2000
YORK URBAN AREA		
Secondary Treatment Plants		
York	2,710,000	7,067,000
Springettsbury	630,000	1,630,000
Dover Twp.	-	630,000
Regional AWT Plant	15,575,000	9,095,000
HANOVER-SPRING GROVE URBAN AREA		
Secondary Treatment Plants		
Hanover	390,000	1,223,000
Penn Twp.	-	841,000
Spring Grove	-	194,000
Regional AWT Plant	4,195,000	2,139,000
SHREWSBURY-NEW FREEDOM-RAILROAD AND GLEN ROCK URBAN AREA		
Secondary Treatment Plants		
Shrewsbury	-	418,000
Glen Rock	-	331,000
Regional AWT Plant	2,045,000	1,577,000
TOTAL TREATMENT CAPITAL COSTS	25,545,000	25,145,000

TABLE III-24

OPERATING COSTS FOR THE SUB-CENTRALIZED AWT - WATER PROCESS ALTERNATIVE

Service Area/ Treatment Plants	Average Annual Treatment Plant Operating Costs ($) 1972 - 1985	1986 - 2000
YORK URBAN AREA		
Secondary Treatment Plants		
York	843,000	1,139,000
Springettsbury	327,000	453,000
Dover Twp.	73,000	149,000
Regional AWT Plant	1,464,000	2,144,000
HANOVER-SPRING GROVE URBAN AREA		
Secondary Treatment Plants		
Hanover	174,000	212,000
Penn Twp.	111,000	139,000
Spring Grove	34,000	40,000
Regional AWT Plant	348,000	419,000
SHREWSBURY-NEW FREEDOM-RAILROAD AND GLEN ROCK URBAN AREA		
Secondary Treatment Plants		
Shrewsbury	82,000	120,000
Glen Rock	34,000	47,000
Regional AWT Plant	178,000	228,000
Subtotal Operating Cost	3,668,000	5,090,000
Transmission Facilities	54,000	96,000
TOTAL OPERATING COSTS	3,722,000	5,186,000

Alternative II

This alternative provides for a comparative cost analysis of centralization of advanced waste treatment vs. upgrading of existing local facilities to high level AWT capabilities as would ultimately be required with a continuation of the present pattern of systems development. AWT treatment plants with high performance (Type D) capabilities are costed for ten local systems. Exhibit III-17 presents the plan for this alternative.

Facilities Requirements

A summary of local AWT facilities requirements through the year 2000 is presented by Table III-25. A cost summary of dispersed AWT facilities is presented in Table III-26. A two stage construction program as in Alternative I is indicated. Transmission pipeline costs (Table III-27) are minor compared to that required in Alternative I.

Facilities Investments

Capital investment costs for treatment and transmission facilities associated with this alternative are given in Table III-27 and 28. Investments for all communities total $36,939,000 in the initial period and $30,844,000 in the second phase. These costs are somewhat greater than for Alternative I.

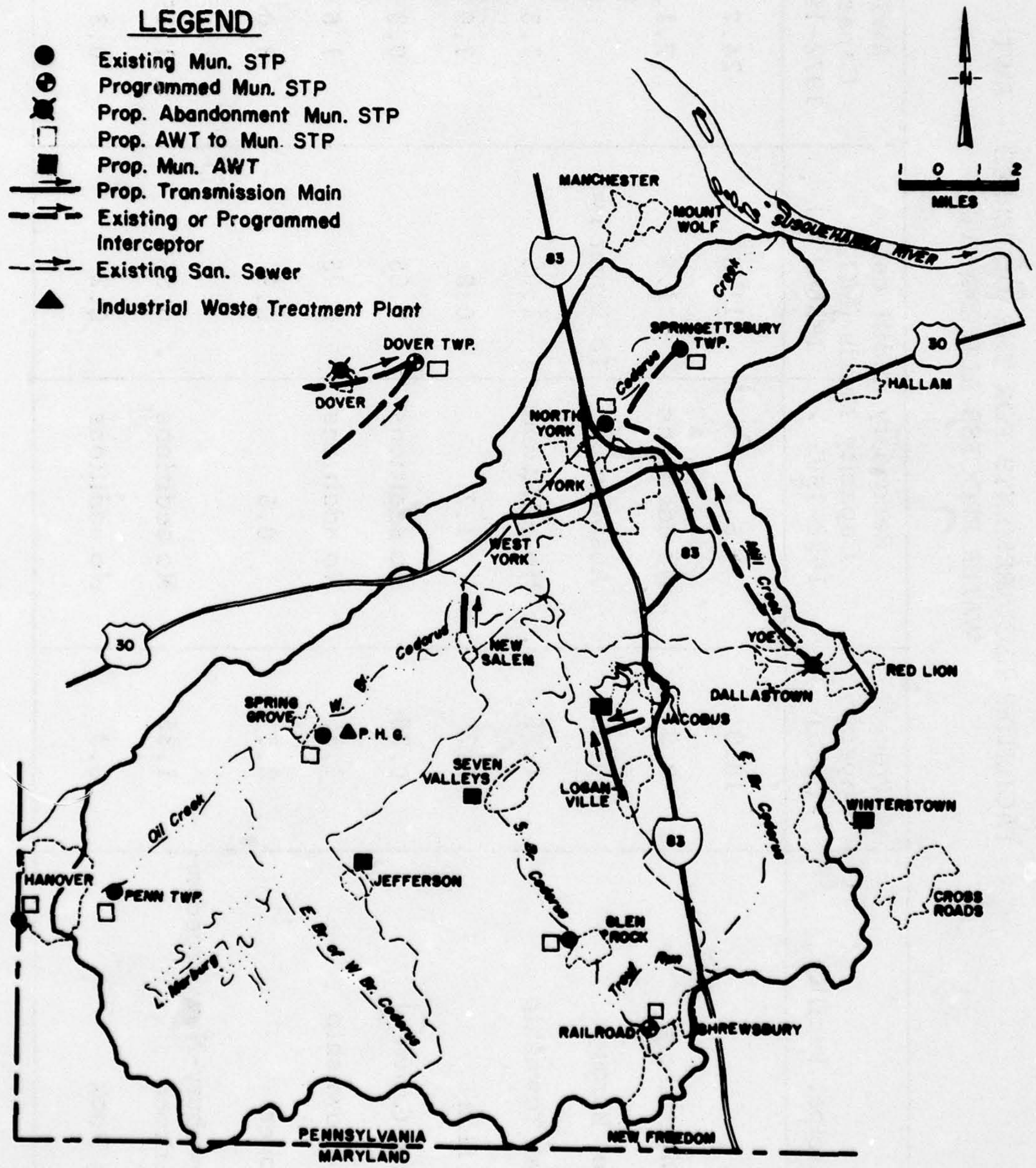
Operating Costs

Average annual operating costs per million gallons for the ten local AWT plants (Table III-29) are $350 in the 1972-85 period and $323 in the 1986-2000 period. These costs are substantially greater than indicated for Alternative I.

Alternative IV

In this plan the upstream urban communities (Hanover, Penn Township, Spring Grove, New Freedom area, Glen Rock, Jefferson, Jacobus, Winterstown, Loganville, and Seven Valleys) are spray irrigated after secondary treatment utilizing the existing local treatment plants where they exist. The York urban area including the Dover, Springettsbury, York, New Salem, and Red Lion service areas is provided advanced treatment at a central regional facility. Exhibit III-18 presents the general plan for this alternative.

CODORUS CREEK DRAINAGE BASIN
ALTERNATIVE II
DISPERSED SYSTEM



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THE CODORUS CREEK WASTEWATER MANAGEMENT STUDY. APPENDIX A. TECH--ETC(U)
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TABLE III-25

FACILITIES REQUIREMENTS FOR THE DISPERSED - AWT WATER PROCESS ALTERNATIVE

Municipal Facility	Present Capacity (MGD)	Secondary Additional Capacity Needs (MGD)		AWT Additional Capacity Needs (MGD)	
		1972-1985	1986-2000	1972-1985	1986-2000
York	18.0	6.7	11.3	24.7	11.3
Springettsbury	8.0	No additions	1.8	7.1	2.7
Dover Borough	0.25	Abandon -	To Dover Twp		
Dover Township	1.75	No additions	1.05	1.3	1.5
Red Lion	0.7	1.2	0.8	1.9	0.8
Spring Grove	0.25	No additions	0.05	0.3	No additions
Penn Township	1.75	No additions	0.45	1.6	0.6
Hanover	2.5	0.5	0.9	3.0	0.9
Shrewsbury-New Freedom-Railroad	1.35	No additions	0.55	1.15	0.75
Glen Rock	0.3	No additions	0.2	0.3	0.2

TABLE III-26

COST SUMMARY FOR THE DISPERSED
AWT - WATER PROCESS ALTERNATIVE

	Cost ($) 1972-1985	Cost ($) 1986-2000
Capital Costs		
Transmission Facilities	2,954,000	-
Secondary Treatment	3,820,000	12,461,000
Advanced Treatment	30,165,000	18,383,000
Sub-Total	36,939,000	30,844,000
Contingencies (20%)	7,388,000	6,169,000
Sub-Total	44,327,000	37,013,000
Engineering (10%)	4,433,000	3,701,000
TOTAL	48,760,000	40,714,000
Average Annual Operating & Maintenance Costs		
Transmission Facilities	36,000	53,000
Secondary Treatment	1,678,000	2,299,000
Advanced Treatment	2,768,000	3,621,000
TOTAL	4,482,000	5,973,000

TABLE III-27

CAPITAL COSTS OF INTERCEPTORS AND PIPELINES
FOR THE DISPERSED AWT - WATER PROCESS ALTERNATIVE

YORK URBAN AREA		
York STP - York AWT treated waste pipeline		
Pumping Station	600,000	
1,400 LF of 48" FM	109,000	
		709,000
Springettsbury STP - Springettsbury AWT		
Pumping Station	90,000	
		90,000
Dover Twp. STP - Dover AWT		
Pumping Station	70,000	
		70,000
RED LION-DALLASTOWN-YOE URBAN AREA		
Red Lion STP - Red Lion AWT		
Pumping Station	70,000	
		70,000
SHREWSBURY-NEW FREEDOM-RAILROAD AND GLEN ROCK URBAN AREA		
Glen Rock STP - Glen Rock AWT		
Pumping Station	55,000	
		55,000
Shrewsbury STP - Shrewsbury AWT		
Pumping Station	60,000	
		60,000
HANOVER-SPRING GROVE URBAN AREA		
Hanover STP - Hanover AWT		
Pumping Station	80,000	
		80,000
Penn Twp. STP - Penn Twp AWT	60,000	
		60,000
Spring Grove STP - Spring Grove AWT		
Pumping Station	35,000	
		35,000
MAJOR AREAS SUBTOTAL		1,229,000

TABLE III-27 (Cont'd)

CAPITAL COSTS OF INTERCEPTORS AND PIPELINES
FOR THE DISPERSED AWT - WATER PROCESS ALTERNATIVE

Small Urban Area Facilities		
Jefferson - Seven Valleys interceptor		
25,200 LF of 8" GR	352,000	
		352,000
Seven Valleys - Reynolds Mill interceptor		
27,300 LF of 8" GR	382,000	
		382,000
Reynolds Mill - Spray interceptor		
Pumping Station (2 Stage Sta)	100,000	
14,000 LF of 12" FM	210,000	
3,100 LF of 10" GR	54,000	
		364,000
Loganville & Jacobus - Reynolds Mill interceptor		
7,100 LF of 8" GR	100,000	
9,700 LF of 8" & 10" GR	155,000	
3,200 LF of 8" GR	45,000	
		300,000
New Salem - York interceptor		
Pumping Station	30,000	
9,400 LF of 6" FM	82,000	
1,200 LF of 8" GR	17,000	
		129,000
Winterstown - Red Lion interceptor		
Pumping Station	30,000	
22,400 LF of 6" FM	168,000	
		198,000
Small Urban Area Subtotal		1,725,000
TOTAL CAPITAL COST OF ALL TRANSMISSION FACILITIES		2,954,000

TABLE III-28

CAPITAL COSTS FOR THE DISPERSED - AWT
WATER PROCESS ALTERNATIVE

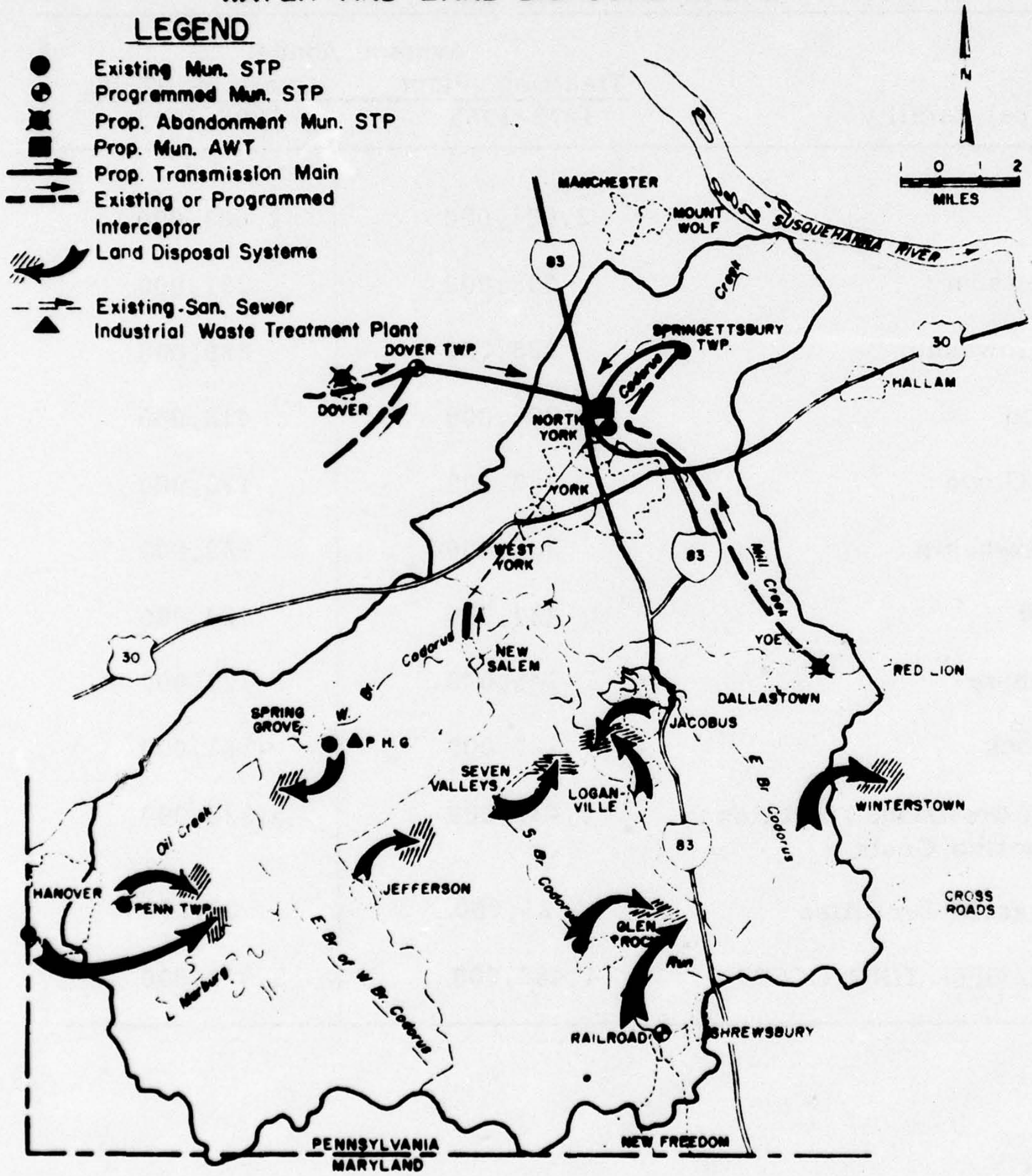
Municipal Facility	1972-1985 Capital Costs ($) Secondary Plant	AWT Plant	Total	1986-2000 Capital Costs ($) Secondary Plant	AWT Plant	Total
York	2,710,000	12,100,000	14,810,000	7,067,000	7,080,000	14,147,000
Springettsbury	-	5,080,000	5,080,000	972,000	2,970,000	3,942,000
Dover Township	-	1,930,000	1,930,000	630,000	2,090,000	2,720,000
Red Lion	720,000	2,410,000	3,130,000	785,000	1,460,000	2,245,000
Spring Grove	-	780,000	780,000	194,000	-	194,000
Penn Township	-	2,160,000	2,160,000	841,000	1,218,000	2,059,000
Hanover	390,000	3,120,000	3,510,000	1,223,000	1,565,000	2,788,000
Shrewsbury	-	1,805,000	1,805,000	418,000	1,400,000	1,818,000
Glen Rock	-	780,000	780,000	331,000	600,000	931,000
TOTAL TREATMENT CAPITAL COSTS	3,820,000	30,165,000	33,985,000	12,461,000	18,383,000	30,844,000

TABLE III-29

OPERATING COSTS FOR THE DISPERSED - AWT WATER PROCESS ALTERNATIVE

Municipal Facility	Average Annual Treatment Plant Operating Costs 1972-1985	1986-2000
York	2,001,000	2,681,000
Springettsbury	695,000	931,000
Dover Township	223,000	389,000
Red Lion	285,000	410,000
Spring Grove	127,000	133,000
Penn Township	306,000	368,000
Hanover	437,000	524,000
Shrewsbury	245,000	323,000
Glen Rock	127,000	161,000
Subtotal Treatment Facilities Operating Costs	4,446,000	5,920,000
Transmission Facilities	36,000	53,000
TOTAL OPERATING COSTS	4,482,000	5,973,000

CODORUS CREEK DRAINAGE BASIN
ALTERNATIVE IV
WATER AND LAND DISPOSAL SYSTEM



Facilities Requirements

This alternative is sub-divided into the York area and upstream community portions.

York Urban Area: - Facilities for this part of the plan are similar to those for the York urban area portion of Alternative I with the exception that the small communities of Winterstown, Loganville, Jacobus and Jefferson are excluded. Table III-30 lists the treatment facilities needs.

Secondary treatment for all waste flows from the York, Springettsbury, Red Lion and Dover service areas would be provided at the York, Dover Township and Springettsbury facilities. Capacities of these plants would be expanded as required and the present York treatment plant would require a major rehabilitation in the late 1980's. The Red Lion treatment plant would be abandoned to permit the use of the Mill Creek interceptor for the transport of all wastes originating in the Red Lion-York development corridor. The York area Type D AWT would be located adjacent to the York secondary treatment plant as presented in Alternative I.

A cost summary for this plan is shown in Table III-31. Transmission facilities required to link the secondary treatment plants with the AWT plant are listed in Table III-32.

Upstream Communities: - Land irrigation to achieve high level advanced waste treatment can accomplish the highest level of dependable performance for the communities in the upper basin with only moderate land requirements. For the ten communities in this group, the total year 2000 estimated flow is 9.35 MGD. This would require 1,800 acres of irrigation area at the design basis rate of 2" per week for 8 months annual operation. Net irrigation and gross site areas required by each of the upstream communities for its year 2000 projected flows are presented in Table III-33.

Geological, soils and engineering feasibility studies of site opportunities (Annex A) have identified the Schist and Phyllite terrainal areas as being the only environmental units generally suitable for land irrigation of wastewater in the Codorus Basin. These two units are easily accessable to all of the upstream communities.

The topography of the Schist and Phyllite areas is steep sloped to rolling with well defined ridge areas. For any significiant size irrigation site, up to 1/3 of the gross site area would have slopes greater than 15 percent and therefore not be irrigable.These steeper slope areas can be

TABLE III-30

FACILITIES REQUIREMENTS FOR THE WATER-LAND ALTERNATIVE

Service Area Treatment Plants	Present Capacity (MGD)	Secondary Additional Capacity Needs (MGD) 1972-1985	Secondary Additional Capacity Needs (MGD) 1986-2000	AWT/Land Irrigation Additional Capacity Needs (MGD) 1972-1985	AWT/Land Irrigation Additional Capacity Needs (MGD) 1986-2000
YORK URBAN AREA					
York	18	6.3	11.2	34.6	16.2
Springettsbury	8	1.0	3.5	-	-
Dover Township	1.75	no additions	1.0	-	-
Dover Borough	0.25	abandon - to Dover Twp.			
Red Lion	0.7	abandon - to Springettsbury			
HANOVER URBAN AREA					
Hanover	2.5	0.5	0.9	4.6	1.5
Penn Township	1.75	no additions	0.45		
SPRING GROVE URBAN AREA	0.25	no additions	0.05	0.3	no additions
SHREWSBURY-NEW FREEDOM-RAILROAD & GLEN ROCK URBAN AREA					
Glen Rock	0.3	no additions	0.2	1.45	0.95
Railroad-New Freedom	1.35	no additions	0.55		
JACOBUS-LOGANVILLE URBAN AREA	-	0.41	no additions	0.41	no additions
SEVEN VALLEYS URBAN AREA	-	0.07	no additions	0.07	no additions
JEFFERSON URBAN AREA	-	0.04	no additions	0.04	no additions
WINTERSTOWN URBAN AREA	-	0.03	no additions	0.03	no additions

TABLE III-31

COST SUMMARY FOR THE
WATER-LAND ALTERNATIVE

	Cost ($) 1972-1985	Cost ($) 1986-2000
Capital Costs		
Transmission Facilities	4,795,000	-
Secondary Treatment	3,746,000	12,229,000
Advanced Treatment	26,311,000	9,925,000
Sub-Total	34,852,000	22,154,000
Contingencies (20%)	6,970,000	4,431,000
Sub-Total	41,822,000	26,585,000
Engineering (10%)	4,182,000	2,659,000
TOTAL	46,004,000	29,244,000
Average Annual Operating & Maintenance Costs		
Transmission Facilities	71,000	122,000
Secondary Treatment	1,674,000	2,289,000
Advanced Treatment	1,621,000	2,350,000
TOTAL	3,366,000	4,761,000

TABLE III-32

CAPITAL COSTS OF INTERCEPTOR AND PIPELINES
FOR THE WATER-LAND ALTERNATIVE

YORK URBAN AREA		
York STP - York AWT treated waste pipeline		
Pumping Station	600,000	
1,400 LF of 48" FM	109,000	
		709,000
Springettsbury to York treated waste pipeline		
Pumping Station	105,000	
21,500 LF of 36" FM	1,180,000	
		1,285,000
Dover-York treated waste pipeline		
Pumping Station	70,000	
27,500 LF of 18" FM	688,000	
		758,000
HANOVER URBAN AREA		
Hanover STP - Irrigation Site treated waste pipeline		
Pumping Station	80,000	
30,500 LF of 20" FM	763,000	
		843,000
Penn Twp. STP - Irrigation Site treated waste pipeline		
Pumping Station	70,000	
8,100 LF of 16" FM	162,000	
		232,000
SPRING GROVE URBAN AREA		
Spring Grove STP - Irrigation Site treated waste pipeline		
Pumping Station	35,000	
9,500 LF of 6" FM	71,000	
		106,000
SHREWSBURY-NEW FREEDOM-RAILROAD AND GLEN ROCK URBAN AREA		
Shrewsbury STP - Irrigation Site treated waste pipeline		
Pumping Station	70,000	
12,700 LF of 16" FM	254,000	
		324,000

TABLE III-32 (Cont'd)

CAPITAL COSTS OF INTERCEPTOR AND PIPELINES
FOR THE WATER-LAND ALTERNATIVE

SHREWSBURY-NEW FREEDOM-RAILROAD AND GLEN ROCK URBAN AREA (Cont'd)		
Glen Rock STP - Irrigation Site treated waste pipeline		
Pumping Station	55,000	
12,200 LF of 8" FM	122,000	
		177,000
MAJOR URBAN AREAS SUBTOTAL		4,434,000
Small Urban Area Facilities		
JACOBUS-LOGANVILLE URBAN AREA		
Jacobus-Loganville Pump Station A raw waste pipeline		
Pumping Station	30,000	
5,200 LF of 10" FM	65,000	
		95,000
Loganville - Pump Sta A - Irrigation Site raw waste pipeline		
Pumping Station	40,000	
5,300 LF of 8" GR (To Sta. A)	74,000	
3,300 LF of 10" FM (To Site)	41,000	
		155,000
SEVEN VALLEYS URBAN AREA		
Seven Valleys - Irrigation Site raw waste pipeline		
Pumping Station	30,000	
1,000 LF of 6" FM	8,000	
		38,000
JEFFERSON URBAN AREA		
Jefferson - Irrigation Site raw waste pipeline		
Pumping Station	30,000	
600 LF of 4" FM	3,000	
		33,000

TABLE III-32 (Cont'd)

CAPITAL COSTS OF INTERCEPTOR AND PIPELINES
FOR THE WATER-LAND ALTERNATIVE

WINTERSTOWN URBAN AREA		
Winterstown - Irrigation Site raw waste pipeline		
Pumping Station	30,000	
2,000 LF of 4" FM	10,000	
		40,000
Small Urban Area Subtotal		361,000
TOTAL CAPITAL COST OF ALL TRANSMISSION FACILITIES		4,795,000

TABLE III-33

IRRIGATION LAND REQUIREMENTS FOR THE UPSTREAM COMMUNITIES OF THE CODORUS BASIN

	Land Requirements		
	1985	2000	
Service Area	Net	Net	Gross
Hanover-Penn Township	900	1,200	2,360
Glen Rock - Shrewsbury	270	450	1,085
Jacobus - Loganville	60	80	176
Spring Grove	44	60	118
Seven Valleys	14	14	39
Jefferson	8	8	33
Winterstown	6	6	33
	1,302	1,818	3,844

NOTE: Net land requirements = actual required irrigation area

Gross land requirements = total required site area with allowance for storage lagoon area, buffer areas and unusable parcels

used for storage ponds or kept forested for wildlife propagation. The general irrigation site area selected for each of the communities is identified in Exhibit III-18.

For the communities of Hanover, Penn Township, Spring Grove, Glen Rock and Railroad-New Freedom, secondary biological treatment would continue to be provided at the present treatment plants. After treatment the wastes would be pumped to the irrigation site storage pond and then irrigated.

The land treatment system for the communities of Loganville, Jacobus, Jefferson and Seven Valleys would have incorporated an aerated lagoon or package type treatment plant to provide secondary treatment before discharge to the storage pond.

Facilities Investments

Capital costs of treatment facilities for the water-land alternative are summarized in Table III-34. Cost items for the York area AWT are similar to those discussed for Alternative I. Cost items for the land treatment systems are presented in greater detail by Table III-35.

Major cost factors in the land system include transmission, storage, irrigation facilities, drainage and site acquisition. A major component of site acquisition for the larger sites is the cost of acquiring residential housing on and adjacent to the site and the relocation of the residents.

A tabulation of the number of homes that must be acquired and residents relocated under a range of assumptions is presented in Table III-36.

In the housing-short York area the salvage of these structures, through relocation, is highly feasible; most are of good quality and worth over $20,000.

To maximize the effective recoverable value of these residences and to internalize it to the project, it is suggested that a formal program for the relocation and resale of acquired residences be considered as part of the project.

The regional authority or a contractor to the authority could establish one or more villages for either special or general residential use. Site parcels, streets, water supply and sewerage could be provided. The acquired structures would then be relocated to these village sites and

TABLE III-34

CAPITAL COSTS FOR THE WATER-LAND ALTERNATIVE

Service Area/ Treatment Plants	Treatment Facility 1972-1985	Capital Costs ($) 1986-2000
YORK URBAN AREA		
Secondary Treatment Plants		
York	2,580,000	6,967,000
Springettsbury	630,000	1,625,000
Dover Township	-	630,000
Regional AWT Plant	15,400,000	9,025,000
HANOVER URBAN AREA		
Secondary Treatment Plants		
Hanover	390,000	1,223,000
Penn Township	-	841,000
Land Irrigation Site	6,129,000 (5,609,000)[a]	500,000
SPRING GROVE URBAN AREA		
Secondary Treatment Plant	-	194,000
Land Irrigation Site	378,000	-
SHREWSBURY-NEW FREEDOM-RAILROAD AND GLEN ROCK URBAN AREA		
Secondary Treatment Plants		
Glen Rock	-	331,000
Shrewsbury	-	418,000
Land Irrigation Site	3,428,000 (3,286,000)[a]	400,000
JACOBUS-LOGANVILLE URBAN AREA		
Secondary Treatment Plant	91,500	-
Land Irrigation Site	559,000	-
SEVEN VALLEYS URBAN AREA		
Secondary Treatment Plant	20,000	-
Land Irrigation Site	165,000	-

TABLE III-34 (Cont'd)

CAPITAL COSTS FOR THE WATER-LAND ALTERNATIVE

Service Area/ Treatment Plants	Treatment Facility 1972-1985	Capital Costs ($) 1986-2000
JEFFERSON URBAN AREA		
Secondary Treatment Plant	17,500	-
Land Irrigation Site	133,000	-
WINTERSTOWN URBAN AREA		
Secondary Treatment Plant	16,500	-
Land Irrigation Site	119,000	-
TOTAL TREATMENT FACILITIES CAPITAL COSTS	30,056,500 (29,394,000)[a]	22,154,000

[a]Includes Salvage of Relocated Buildings

TABLE III-35

CAPTIAL COSTS
UPPER BASIN LAND TREATMENT SYSTEMS
LAND IRRIGATION SITE
(Costs in $1,000)

	1972-1985	1985-2000	Total
HANOVER-PENN TWP. URBAN AREA			
Storage Ponds	$ 1,550	$ -	$ 1,550
Distribution Pumping & Piping	382	190	572
Irrigation Machines	265	135	400
Drainage Facilities	337	168	505
Land, Residences, & Relocations	3,602	-	3,602
Total	$ 6,136	$ 493	$ 6,629
SHREWSBURY-NEW FREEDOM-RAILROAD AND GLEN ROCK URBAN AREA			
Storage Ponds	$ 1,630	$ -	$ 1,630
Distribution Pumping & Piping	194	194	388
Irrigation Machines	75	75	150
Drainage Facilities	136	136	272
Land, Residences, & Relocations	1,388	-	1,388
Total	$ 3,423	$ 405	$ 3,828
SPRING GROVE URBAN AREA			
Storage Ponds	$ 170	$ -	$ 170
Distribution Pumping & Piping	26	13	39
Irrigation Machines	13	7	20
Drainage Facilities	19	10	29
Land, Residences, & Relocations	120	-	120
Total	$ 348	$ 30	$ 378
JACOBUS, LOGANVILLE URBAN AREA			
Storage Ponds	$ 87	$ -	$ 87
Distribution Pumping & Piping	37	18	55
Irrigation Machines	20	10	30
Drainage Facilities	38	19	57
Land, Residences, & Relocations	340	-	340
Total	$ 522	$ 47	$ 569

TABLE III-35 (Cont'd)

CAPITAL COSTS
UPPER BASIN LAND TREATMENT SYSTEMS
LAND IRRIGATION SITE
(Costs in $1,000)

	1972-1985	1985-2000	Total
SEVEN VALLEYS URBAN AREA			
Storage Ponds	$ 87	-	$ 87
Distribution Pumping & Piping	33	-	33
Irrigation Machines	8	-	8
Drainage Facilities	8	-	8
Land, Residences, & Relocations	29	-	29
Total	$ 165	-	$ 165
JEFFERSON URBAN AREA			
Storage Ponds	$ 63	-	$ 63
Distribution Pumping & Piping	32	-	32
Irrigation Machines	7	-	7
Drainage Facilities	5	-	5
Land, Residences, & Relocations	25	-	25
Total	$ 132	-	$ 132
WINTERSTOWN URBAN AREA			
Storage Ponds	$ 49	-	$ 49
Distribution Pumping & Piping	32	-	32
Irrigation Machines	7	-	7
Drainage Facilities	5	-	5
Land, Residences, & Relocations	25	-	25
Total	$ 118	-	$ 118

TABLE III-36

RESIDENTIAL HOUSING RELOCATION REQUIREMENTS
UPPER BASIN COMMUNITIES

Site Area	Residential Housing Acquisition Requirements (# of units) Method A	Method B	Total Net Aquisition and Family Relocation Costs Method A (1)	Method A (2)	Method B (1)	Method B (2)
Hanover-Penn Twp	69	32	1,967,000	1,449,000	912,000	672,000
Spring Grove	1	1	28,500	21,000	28,500	21,000
Shrewsbury-Glen Rock	19	10	541,000	399,000	285,000	210,000
Jefferson	0	0	0	0	0	0
Jacobus-Loganville	7	2	199,500	147,000	59,000	420,000
Winterstown	0	0	0	0	0	0
Seven Valleys	0	0	0	0	0	0
		TOTAL	2,736,000	2,016,000	1,284,500	945,000

NOTES:

Method A - Acquisition of all residential structures within site area and those located in strips along roads adjacent to site.

Method B - Acquisition of only those housing units located within site area and those outside the site which cannot economically be buffered by at least a 500 ft. open area.

Conditions of acquisition

(1) Purchase of each structure at an average cost of $25,000 with demolition.

(2) Purchase of each structure at an average cost of $25,000. Each structure would be relocated to a new community development area and resold as part of project;30% net recovery of acquisition cost assumed.

Relocation Costs: $3,000 in adjustments and $500 moving costs.

sold to the public or rented for general or special use. The potential economic benefits of such a program (Table III-37) could be a net savings of over 30 percent in the acquisition cost of these homes.

TABLE III-37

COST SAVINGS FROM RELOCATION OF ACQUIRED IRRIGATION SITE RESIDENCES

Acquisition cost of site residences	$ 25,000
Moving cost for structure relocation	2,500
Village site development costs	
Roads, sewer and water	2,500
Land acquisition	500
Structure foundation and rehabilitation	5,000
Project Administration	1,000
	$ 36,500
Resale of structure	20,000
Net cost of residence acquisition to project	$ 16,500
Equivalent salvage value	34%

Operating Costs

Average annual operating costs for the facilities provided under Alternative IV are summarized in Table III-38 for the 1972-85 and 86-2000 periods. Operating costs for the York AWT system is projected at $256 per million gallons treated as against $305 per million gallons for all the land treatment systems combined during the initial design period.

TABLE III-38

OPERATING COSTS FOR THE WATER-LAND ALTERNATIVE

Service Area/ Treatment Plants	Average Annual Treatment Plant Operating Costs 1972-1985	1986-2000
YORK URBAN AREA		
Secondary Treatment Plants		
York	835,000	1,124,000
Springettsbury	327,000	453,000
Dover Township	73,000	149,000
Regional AWT Plant	1,454,000	2,125,000
HANOVER URBAN AREA		
Secondary Treatment Plants		
Hanover	174,000	212,000
Penn Township	111,000	139,000
Land Irrigation Site	95,000	130,000
SPRING GROVE URBAN AREA		
Secondary Treatment Plant	34,000	40,000
Land Irrigation Site	9,000	10,000
SHREWSBURY-NEW FREEDOM-RAILROAD AND GLEN ROCK URBAN AREA		
Secondary Treatment Plants		
Glen Rock	34,000	47,000
Shrewsbury	82,000	120,000
Land Irrigation Site	33,000	52,000
JACOBUS-LOGANVILLE URBAN AREA		
Secondary Treatment Plant	2,400	3,200
Land Irrigation Site	7,600	9,800
SEVEN VALLEYS URBAN AREA		
Secondary Treatment Plant	500	500
Land Irrigation Site	7,500	8,500

TABLE III-38 (Cont'd)

OPERATING COSTS FOR THE WATER-LAND ALTERNATIVE

Service Area/ Treatment Plants	Average Annual Treatment Plant Operating Costs 1972-1985	1986-2000
JEFFERSON URBAN AREA		
Secondary Treatment Plant	500	500
Land Irrigation Site	7,500	7,500
WINTERSTOWN URBAN AREA		
Secondary Treatment Plant	500	500
Land Irrigation Site	7,500	7,500
Subtotal Treatment Facilities Operating Costs	3,295,000	4,639,000
Transmission Costs	71,000	122,000
TOTAL TREATMENT FACILITIES CAPITAL COSTS	$ 3,366,000	$ 4,761,000

Alternative V

The opportunity for reuse of municipal treatment plant effluents as a water supply source for the P.H. Glatfelter Co. has been discussed in Part III of this report. Incorporation of direct reuse of secondary effluent from the York area permits a major reduction in the capacity requirements and operating costs of facilities required for the remaining flows to be treated.

Two reuse treatment system development options are evaluated for the linking of the York area wastewater flows and the P. H. Glatfelter Co. water supplies needs. One option designated Option A involves re-use and water process AWT treatment of the remaining flow from the York urban area. The other designated Option B considers reuse with land irrigation of the remaining flow.

Option A

This plan involves transmission of the York STP secondary plant effluent to the Glatfelter process water treatment plant. The transmission system would handle only the process water supply needs of the paper mill, estimated to be 23 MGD in 1985 and 28 MGD in the year 2000. Excess wastewater flows would be delivered to a regional AWT located at the site of the present Springettsbury treatment plant. Secondary effluent from the Dover and Springettsbury plants would also be treated at this facility. Exhibit III-19 presents the general system plan.

Facilities Requirements

This plan requires construction of a major pipeline (28 MGD capacity) from the York treatment plant to the paper mill. A large storage reservoir at York is included to detain the effluent at times when quality upsets would make the wastewater unsuited for use in the mill. Storage capacity for 5 days of flow is required to allow for the gradual introduction of this material into the AWT plant for complete treatment.

A complete list of facilities required for this plan is contained in Tables III-39 and 40. A cost summary for the plan is shown in Table III-41.

Improvements required by the P. H. Glatfelter Co. as part of this plan include replacement of the 8 MGD outmoded portion of its water treatment plant and provision of a carbon adsorption treatment system for color

CODORUS CREEK DRAINAGE BASIN

REUSE OPTION A

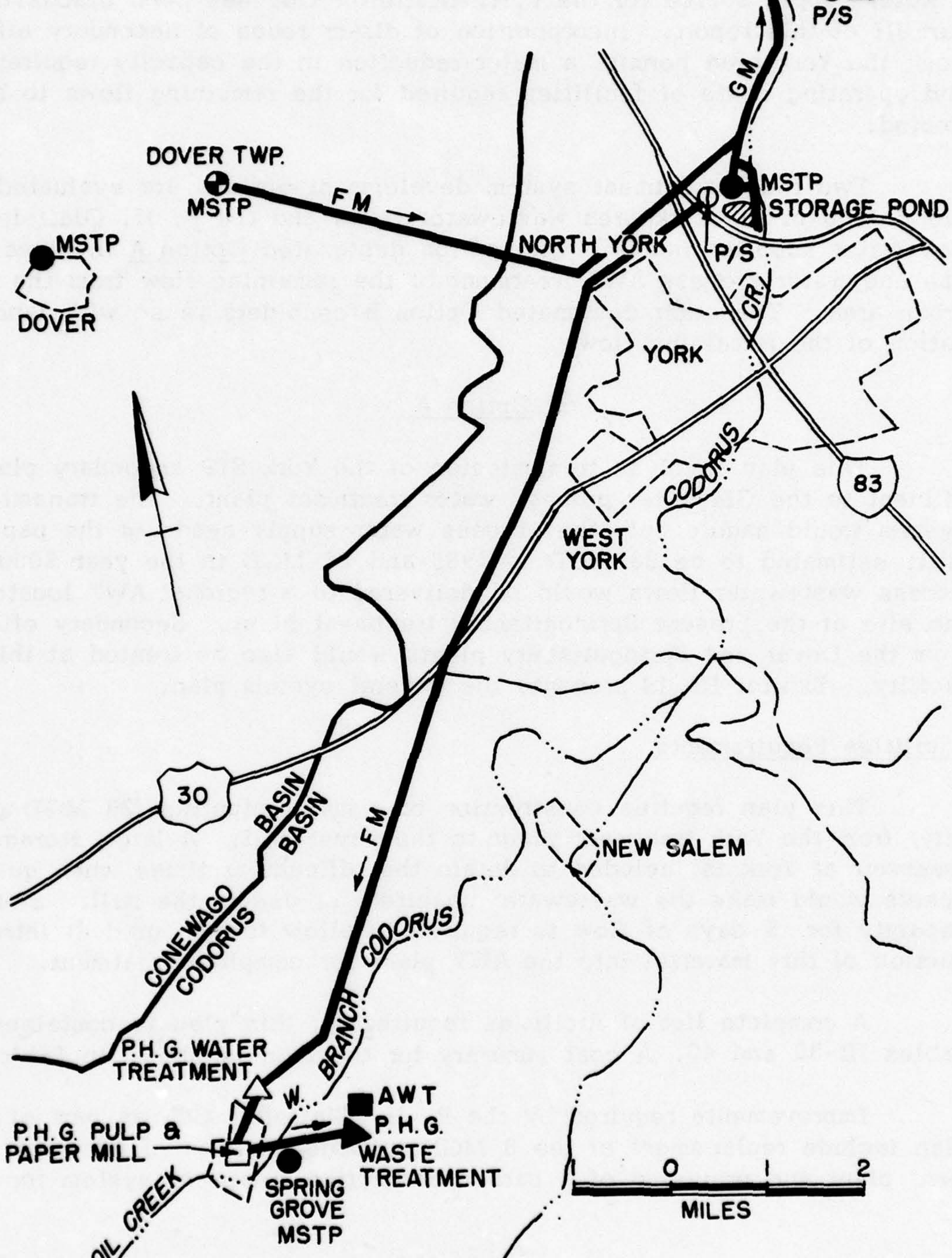


TABLE III-39

TREATMENT FACILITIES REQUIREMENTS

FOR THE REUSE ALTERNATIVE - OPTION A

Municipal Facilities

Service Area/ Treatment Plants	Present Capacity (MGD)	Treatment Plant Facilities (Added Capacity in MGD) 1972-85	1986-2000
YORK URBAN AREA			
Secondary Treatment Plants			
York	18.0	6.7	11.3
Springettsbury	8.0	1.0	3.5
Dover Township	1.75	no additions	1.0
Regional AWT Plant @ Springettsbury		12.0	23.3
Reuse Pipeline		23.0	28.0
P. H. GLATFELTER COMPANY			
Water Treatment Plant	12.0	12.0	4.0
Secondary Treatment	20.0	4.0	4.0
Carbon Filter			
Adsorption System and Reaeration		24.0	4.0

TABLE III-40

CAPITAL COSTS OF TRANSMISSION FACILITIES FOR THE REUSE ALTERNATIVE - OPTION A

		Total Cost
York - Glatfelter treated waste pipeline		
Pumping Station - 35 MGD, TDH=350'	910,000	
58,000 LF of 42" FM	3,650,000	
		4,560,000
Other Facilities		
York - Springettsbury treated waste pipeline		
21,700 LF of 42" GR	1,860,000	
		1,860,000
Dover - York treated waste pipeline		
Pumping Station	70,000	
27,500 LF of 18" FM	688,000	
		758,000
Springettsbury STP - Springettsbury AWT		
Pumping Station 40 MGD, TDH=40'	500,000	
		500,000
Other facilities as in Alternative I (New Salem, Loganville, Jacobus, Seven Valleys and Jefferson)		1,725,000
Total Transmission Facilities Capital Costs		9,403,000

TABLE III-41

COST SUMMARY FOR THE
REUSE ALTERNATIVE - OPTION A

	Cost ($) 1972-1985	Cost ($) 1986-2000
Capital Costs		
Transmission Facilities	9,403,000	-
Secondary Treatment	8,983,000	10,687,000
Advanced Treatment	12,050,000	8,562,000
Sub-Total	30,436,000	19,249,000
Contingencies (20%)	6,087,000	3,859,000
Sub-Total	36,523,000	23,108,000
Engineering (10%)	3,652,000	2,311,000
TOTAL	40,175,000	25,419,000
Average Annual **Operating & Maintenance Costs**		
Transmission Facilities	101,000	138,000
Secondary Treatment	1,468,000	2,026,000
Advanced Treatment	494,000	960,000
TOTAL	2,063,000	3,124,000

and COD removal. Such facilities are required with any alternative to meet water and wastewater treatment needs at the mill. Reaeration facilities are required for additional cooling and increase of effluent oxygen concentrations. All facilities require expansion in capacity to 28 MGD by year 2000.

Facilities Investments

Treatment facilities investment requirements for this plan are presented in Table III-42. Included are those associated with the P. H. Glatfelter Co. water treatment and waste treatment improvements program.

Operating Costs

Estimated operating costs for secondary treatment at the York area plants, advanced treatment at Springettsbury and additional costs for treatment of the secondary effluent to process water standards at the paper mill are presented in Table III-43. The average annual initial period cost per million gallons treated is $191 compared to a cost of $255 for the York area facilities in Alternative I.

Option B

In this plan all wastes from the York area would be transmitted to a large land irrigation site storage reservoir located in the West Branch near the Glatfelter facility. A pipeline from the reservoir would deliver a portion of the wastewater to the paper mill water treatment plant. The remainder would be land irrigated for advanced treatment at a site area adjacent to the storage reservoir. Exhibit III-20 depicts the facilities associated with this plan.

Facilities Requirements

Land requirements to irrigate the remaining York area wastewater flows from that reused at the paper mill are listed below:

Rate	Net Irrigation Area	Total Site Area
1985 - (flow = 11 MGD)	2,140 acres	3,230 acres
2000 - (flow = 23 MGD)	4,460 acres	6,750 acres

TABLE III-42

CAPITAL COSTS

FOR THE REUSE ALTERNATIVE - OPTION A

Treatment Facilities	Treatment Facilities 1972-85	Capital Costs 1986-2000
YORK URBAN AREA		
Secondary Treatment Plants		
York	5,710,000[a]	7,067,000
Springettsbury	630,000	1,630,000
Dover Township		630,000
Regional AWT Plant	7,550,000	7,350,000
Subtotal	13,890,000	16,677,000
P. H. GLATFELTER COMPANY		
Water Treatment Plant	1,368,000	588,000
Secondary Treatment Plant	1,275,000	772,000
Carbon Filter Adsorption System and Reaeration	4,500,000	1,212,000
Subtotal	7,143,000	2,572,000
Total Treatment Facilities Capital Costs	21,033,000	19,249,000

[a] Includes $3 million storage facility for flow detention during upset conditions.

TABLE III-43

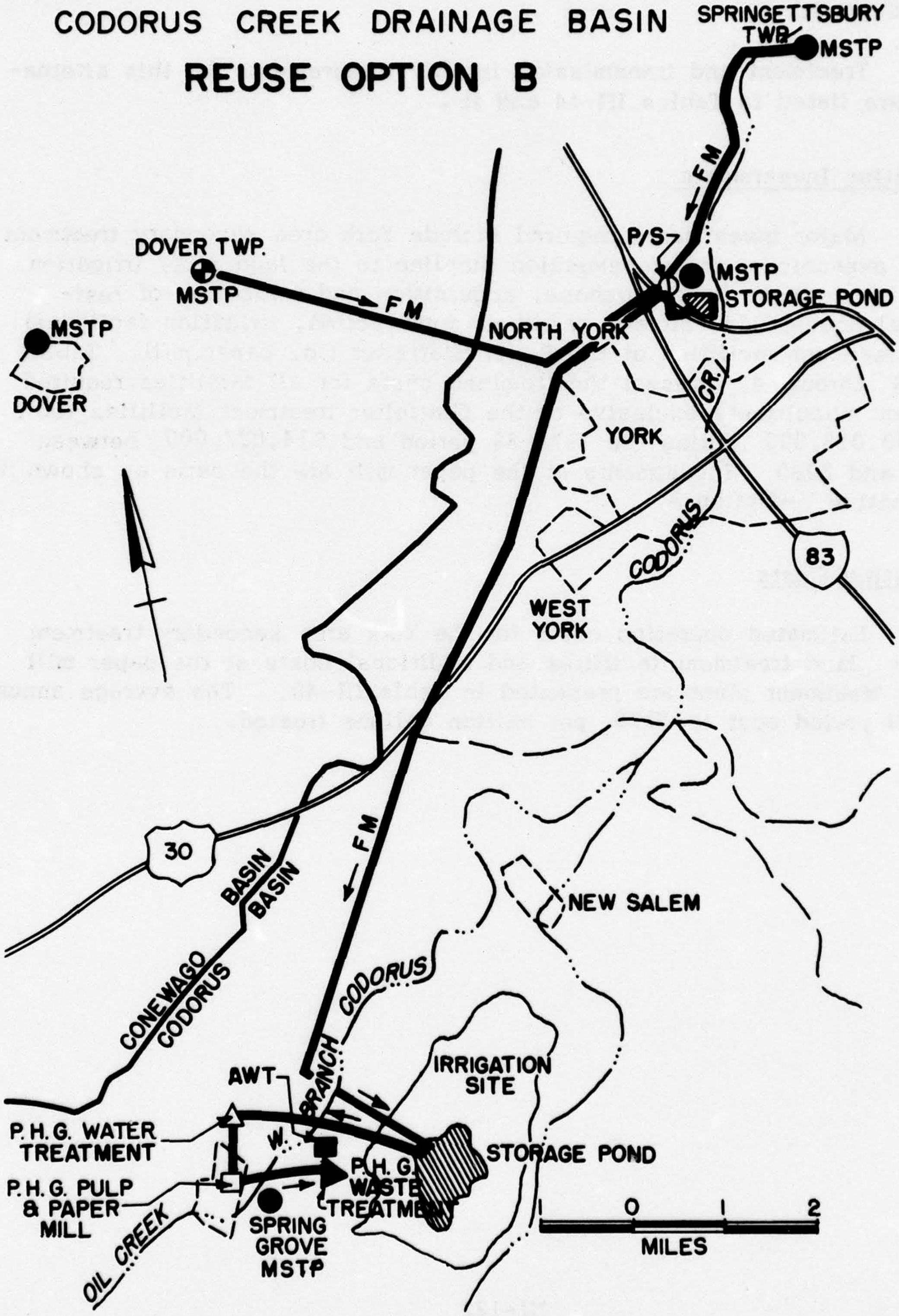
OPERATING COSTS FOR THE REUSE ALTERNATIVE - OPTION A

	Annual Average Treatment Facilities 1972-1985	Operating Costs 1986-2000
Treatment Facilities		
York Area Secondary Treatment Plants		
York	843,000	1,139,000
Springettsbury	327,000	453,000
Dover Township	73,000	149,000
Springettsbury AWT Plant	494,000	960,000
Additional Glatfelter Water Treatment ($30.00/MG)	225,000	285,000
Sub-Total	1,962,000	2,986,000
Transmission Facilities		
York area facilities	14,000	39,000
York-Glatfelter pipeline	87,000	99,000
Sub-Total	101,000	138,000
TOTAL OPERATING COSTS	2,063,000	3,124,000

EXHIBIT III - 20

CODORUS CREEK DRAINAGE BASIN

REUSE OPTION B



A site area meeting the Year 2000 land requirements is identified by Exhibit III-20.

Treatment and transmission facility requirements for this alternative are listed in Tables III-44 and 45.

Facilities Investments

Major investments required include York area secondary treatment plant expansions; the transmission piepline to the land site, irrigation site development (land purchase, acquisition and relocation of residential households, storage reservoir construction, irrigation facilities), and treatment facilities at the P. H. Glatfelter Co. paper mill. Tables III-45 through 47 present the itemized costs for all facilities required. Project investments exclusive of the Glatfelter treatment facilities total to $83,018,000 during the 1972-85 period and $14,027,000 between 1986 and 2000. Investments at the paper mill are the same as shown in Alternative V-Option A.

Operating Costs

Estimated operating costs for the York area secondary treatment plants, land treatment facilities and additional costs at the paper mill water treatment plant are presented in Table III-48. The average annual initial period cost is $178 per million gallons treated.

TABLE III - 44

TREATMENT FACILITIES REQUIREMENTS FOR
THE REUSE ALTERNATIVE - OPTION B

Service Area/ Treatment Plants	Present Capacity (MGD)	Treatment Plant Facility (Added Capacity in MGD) 1972-1985	1986-2000
YORK URBAN AREA			
Secondary Treatment Plants			
York	18.0	6.7	11.3
Springettsbury	8.0	1.0	3.5
Dover Township	1.75	No Additions	1.0
Reuse Pipeline	-	35.0	16.3
Land Irrigation Site	-	11.0	12.3
P. H. GLATFELTER CO.			
Water Treatment Plant	12.0	12.0	4.0
Secondary Treatment Plant	20,0	4.0	4.0
Carbon Filter Adsorption System & Reaeration	-	24.0	4.0

TABLE III-45

CAPITAL COSTS OF TRANSMISSION FACILITIES FOR THE REUSE ALTERNATIVE - OPTION B

		Total Cost
Transmission from York - land treated waste pipeline		
Pumping Station - 90 MGD, TDH=392'	1,870,000	
56,000 LF of 60" FM	5,300,000	
		7,170,000
Transmission from Land Site - P. H. Glatfelter Co. treated waste pipeline		
8,000 LF of 30" GR	350,000	
		350,000
Other facilities as in Alternative I (Dover-York, Springettsbury-York, New Salem, Loganville, Jacobus, Seven Valleys and Jefferson facilities)	5,320,000	5,320,000
Total Transmission Facilities Capital Costs		12,840,000

TABLE III-46

COST SUMMARY FOR THE
REUSE ALTERNATIVE - OPTION B

	Cost ($) 1972-1985	Cost ($) 1986-2000
Capital Costs		
Transmission Facilities	12,840,000	-
Secondary Treatment	5,983,000	10,687,000
Advanced Treatment	21,338,000	5,912,000
Sub-Total	40,161,000	16,599,000
Contingencies (20%)	8,032,000	3,320,000
Sub-Total	48,193,000	19,919,000
Engineering (10%)	4,819,000	1,992,000
TOTAL	53,012,000	21,911,000
Average Annual Operating & Maintenance Costs		
Transmission Facilities	232,000	345,000
Secondary Treatment	1,468,000	2,026,000
Advanced Treatment	220,000	368,000
TOTAL	1,920,000	2,739,000

TABLE III-47

CAPITAL COSTS FOR THE REUSE ALTERNATIVE - OPTION B

Treatment Facilities	Treatment Facilities 1972-1985	Capital Costs 1986-2000
YORK URBAN AREA		
Secondary Treatment Plants		
York	2,710,000	7,067,000
Springettsbury	630,000	1,630,000
Dover Township	-	630,000
Land Irrigation Site	16,838,000	4,700,000
Subtotal	20,178,000	14,027,000
P. H. GLATFELTER CO.		
Water Treatment Plant	1,368,000	588,000
Secondary Treatment Plant	1,275,000	772,000
Carbon Filter Adsorption System & Reaeration	4,500,000	1,212,000
Subtotal	7,143,000	2,572,000
TOTAL TREATMENT FACILITIES CAPITAL COSTS	27,321,000	16,599,000

TABLE III-48

OPERATING COSTS
REUSE ALTERNATIVE V - OPTION B

	1972-1985	1986-2000
Treatment Facilities		
York area secondary treatment plants		
York	843,000	1,139,000
Springettsbury	327,000	453,000
Dover Township	73,000	149,000
Land irrigation site	220,000	368,000
Additional Glatfelter water and wastewater treatment	225,000	285,000
Sub-Total	1,688,000	2,394,000
Transmission Facilities		
York area facilities	19,000	45,000
York - land site pipeline	213,000	300,000
Sub-Total	232,000	345,000
Total Operating Costs	1,920,000	2,739,000

Cost Evaluation of Alternatives

Comparative review of the cost implications of alternatives requires joint consideration of the capital and operating components. Management strategies for the entire study area and sub-area elements of each strategy must also be reviewed. This permits the formulation of the most cost-effective combination of elements for the final plan.

A cost comparison of the individual separate alternatives presented is provided with Table III- 49. In this table capital costs are converted to annual costs using a 6 percent-30 year amortization schedule. For the three basic alternatives the combination water-land plan has the least average annual cost (capital and operating). However, both reuse options offer significantly lower costs if they can be implemented.

A comparison of sub-area costs for the upper basin areas is made in Tables III- 50 & 51. In both the Hanover-Spring Grove and Glen Rock-Shrewsbury areas the combination water-land is the least costly of the three basic choices.

For the York area, Table III-52 compares the basic and the two reuse alternatives. Regionalization is shown to be significantly less costly than the individual plant up-grading plan. The economies inherent in the reuse options are made more apparent.

In summary, the combination land-water alternative is indicated to be the most efficient cost choice for each area short of the implementation of one of the reuse alternatives. Reuse offers substantial cost savings to the York area. Reuse in the York urban area coupled with land treatment in the upper basin area presents the lowest cost, high performance course of preferred action.

TABLE III-49

COST COMPARISON OF FINAL

WASTEWATER TREATMENT ALTERNATIVES

Cost Component		Sub-Centralized AWT	Dispersed AWT	Water-Land	Reuse - Option A[a]	Reuse - Option B[a]
Total Capital Cost[a]	1972-85	$41,046,000	$48,021,000	$45,325,000	$45,890,000	$58,533,000
	1986-2000	32,689,000	40,097,000	28,800,000	26,759,000	23,314,000
(Treatment & Transmission)	Total Period	73,735,000	88,118,000	74,125,000	72,649,000	81,847,000
Annual Capital	1972-85	2,982,000	3,489,000	3,293,000	3,334,000	4,252,000
Cost @ 6%	1986-2000	5,357,000	6,402,000	5,385,000	5,278,000	5,946,000
For 30 years						
Average Annual	1972-85	3,722,000	4,482,000	3,366,000	2,659,000	2,516,000
Operating Costs	1986-2000	5,186,000	5,973,000	4,761,000	3,913,000	3,528,000
(Treatment & Transmission)						
Total Average	1972-85	6,704,000	7,971,000	6,659,000	5,993,000	6,768,000
Annual Cost	1986-2000	10,543,000	12,375,000	10,146,000	9,191,000	9,474,000
	Total Period	8,624,000	10,173,000	8,403,000	7,592,000	8,121,000

[a]Costs Do Not Reflect Treatment of Gletfelter's Wastewater. Costs for Areas Outside the York Urban Area Reflect Advanced Waste Treatment by the Land Method. Capital costs include 30% for contingencies and engineering fees, etc.

TABLE III-50

COST COMPARISON OF THE FINAL WASTEWATER TREATMENT
ALTERNATIVES FOR THE HANOVER - SPRING GROVE URBAN AREAS

Cost Component		Alternative: Sub-Centralized AWT	Dispersed AWT	Water - Land
Total Capital Cost	1972-85	7,389,000	8,613,000	10,501,000
	1986-2000	5,716,000	6,533,000	3,585,000
(Treatment & Trans)	Total Period	13,105,000	15,146,000	14,086,000
Annual Capital Cost	1972-1985	537,000	626,000	763,000
@ 6% for 30 years	1986-2000	952,000	1,100,000	1,023,000
Average Annual	1972-1985	673,000	872,000	439,000
Operating Costs	1986-2000	820,000	1,027,000	557,000
(Treatment & Trans.)				
Total Average	1972-1985	1,210,000	1,498,000	1,202,000
Annual Cost	1986-2000	1,772,000	2,127,000	1,580,000
	Total Period	1,491,000	1,813,000	1,391,000

TABLE III-51

COST COMPARISON OF THE FINAL WASTEWATER
TREATMENT ALTERNATIVES FOR THE SHREWSBURY-NEW FREEDOM-
RAILROAD AND GLEN ROCK URBAN AREAS

Cost Component		ALTERNATIVE Sub-Centralized AWT	Dispersed AWT	Water-Land
Total Capital	1972-85	3,247,000	3,510,000	5,108,000
Cost	1986-2000	3,024,000	3,574,000	1,494,000
(Treatment & Trans.)	Total Period	6,271,000	7,084,000	6,602,000
Annual Capital	1972-85	236,000	255,000	371,000
Cost @6%	1986-2000	456,000	515,000	480,000
for 30 Yrs.				
Annual Average	1972-85	295,000	372,000	157,000
Operating Cost	1986-2000	397,000	485,000	232,000
Total Average	1972-85	531,000	627,000	528,000
Annual Cost	1986-2000	853,000	1,000,000	712,000
	Total Period	692,000	814,000	620,000

TABLE III-52

COST COMPARISON OF THE FINAL WASTEWATER
TREATMENT ALTERNATIVES FOR THE YORK URBAN AREA

Cost Component		ALTERNATIVE Sub-Centralized AWT	Dispersed AWT	Water-Land	Reuse Option A	Reuse Option B
Total Capital Cost (Treatment & Trans.)	1972-85	30,410,000	35,898,000	29,715,000	30,281,000	42,923,000
	1986-2000	23,949,000	29,970,000	23,721,000	21,680,000	18,235,000
	Total Period	54,359,000	65,868,000	53,436,000	51,961,000	61,158,000
Annual Capital Cost @ 6% for 30 Yrs.	1972-85	2,209,000	2,608,000	2,159,000	2,200,000	3,118,000
	1986-2000	3,949,000	4,785,000	3,882,000	3,775,000	4,443,000
Average Annual Operating Costs (Treatment & Trans.)	1972-85	2,755,000	3,237,000	2,770,000	2,063,000	1,920,000
	1986-2000	3,970,000	4,461,000	3,972,000	3,124,000	2,739,000
Total Average Annual Cost	1972-85	4,964,000	5,845,000	4,929,000	4,263,000	5,038,000
	1986-2000	7,919,000	9,246,000	7,854,000	6,899,000	7,182,000
	Total Period	6,442,000	7,546,000	6,392,000	5,581,000	6,110,000

PHYSICAL CHARACTERISTICS OF CODORUS CREEK BASIN, PENNSYLVANIA RELATIVE TO WASTEWATER APPLICATION

by

James E. Hackett and Associates
Geologic Consultants

Blackburg, Virginia
January, 1972

CONTENTS

SUMMARY STATEMENT

Data compiled in the course of this physical feasibility study indicate that average permeabilities of the soil profile as determined through short-term infiltration tests are adequate to accommodate wastewater application rates in the order of two inches per week on Chester and Manor soils in the Phyllite and Schist terrains. However, these data also indicate that soil profile permeability in these areas is subject to a wide range in values as a result of local variations in soil texture and structure and that local variation can be a complicating factor in site development. In addition, the effects of application procedures on infiltration capacities of soils of this type are not well enough understood to establish what the effective infiltration rates might be under operating conditions.

Soil profiles developed on the Conestoga limestone within the Hanover-York Valley physiographic unit are too low in permeability to permit infiltration of wastewater applied at rates in the order of two inches per week without excessive puddling and ponding. Soils developed on the Triassic bedrock are generally less than 3 feet thick and the adequacy of these soils to provide for efficient polishing of applied wastewater is questioned.

Because of the restricted permeability and storage capacity of subsurface units within the Codorus Creek Basin, artificial drainage control measures by wells or ditches will be required to discharge laterally the quantity of infiltrate resulting from land application of wastewater. Because of depth of excavation required to establish effective gradients and because of construction problems in indurated rock terrains with uneven soil cover conditions, ditching is not likely to be an effective or economic drainage control measure.

Drainage control by wells can be an effective drainage control mechanism. However, the variability of permeability characteristics in materials with joint and fracture permeability indicates that the utility and effectiveness of drainage control by wells and the number and spacing of drainage control wells will be dependent on local site characteristics and will probably have to be established through empirical processes at each site.

Topography will exert a strong influence on extent and conformation of application areas, especially in the Phyllite and Schist

terrains. Most favorable slope conditions are present in the upland areas adjoining drainage divides. Owing to the relatively high relief, groundwater divides should closely approximate major surface drainage divides and the relief of the groundwater surface should be sufficiently large so that regional groundwater flow patterns would be retained without major alteration by land application activities.

Large, contiguous areas of suitable slope (less than 15 percent) are present in the area of the Phyllite terrain especially in the region south of and adjacent to the Hanover-York Valley. Areas of suitable slope conditions are likely to be more restricted in the Schist terrain especially in the area of the Wissahickon schist which underlies the most southerly and southeasterly part of this drainage basin.

In general, operating requirements for land application of wastewater and physical capability to accommodate such activities are of the same order of magnitude in the Codorus Creek Basin. As a consequence there is not a large differential between operating requirements and physical constraints in terms of infiltration capacity, transmissivity or unit operation areas of suitable dimension. In the design stage of the investigation, more extensive site area investigations will have to be conducted to establish these factors specifically for determination of site suitability and site management requirements.

GENERAL SETTING

The Codorus Creek drainage basin lies within four physiographic subdivisions of the Piedmont Province.[1] Associated with each of these physiographic units are characteristic rock types which determine the fundamental topographic form, soil development and surface and subsurface drainage. The distribution of geoloigic units within the basin along with major structural features shown on Figure 1 summarized are from the geologic map of York County, Pennsylvania by Stose and Jones,[2]. The distribution of soil associations and the boundaries between the physiographic units are presented in Figure 2.

Gettysburg Plain

The Gettysburg Plain forms an extensive physiographic subdivision of the Piedmont Province on the northwest flank of the Codorus Creek Basin. Only a small part of the basin, that generally occuring between Manchester and Emigsville and extending southwest to about Shiloh, lies within this unit.

The Gettysburg Plain if formed on the soft and easily eroded red shades and sandstones of Triassic Age and is characterized by broad shallow valleys and low ridges. Within the Codorus Creek Basin, this plain is underlain by the shales and sandstones of the New Oxford Formation. The thin bedded character of the rocks (individual units are often less than 20 feet in thickness) along with the northwesterly dip of the formation, results in rapid changes in texture within short lateral distances on the land surface.

The soils developed on the New Oxford Formation are predominantly those of the Penn-Lansdale-Readington association. They are generally thin and bedrock occurs within 3 feet of land surface. The soils range in composition from sandy loam to clay loam and silt loams are the predominant textural class. Topography is nearly level to

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[1] U. S. Dept. of Agriculture Soil Conservation Service, Soil Survey York County, Pennsylvania, Series 1959 No. 23, May, 1963, p. 152.

[2] Stose, George W. and Jones, Anna I., Geologic Map of York County, Pennsylvania; Pennsylvania Topographic and Geologic Survey, Bulletin C-67, Plate I, 1939 (reprinted 1970).

gently sloping but short, moderately-steep slopes occur along drainageways.

Hills

The Hills physiographic unit, including the Hellam Hills and Pigeon Hills subdivisions, is an area of high knolls and elongated ridges formed quartzite bedrock highly resistant to erosion. Slopes are long and steep to moderately steep and ridge crests are narrow with widths of less than 100 yards. The soils are those of the Edgemont-Highfield-Murrill association and range from silt to sandy loam in texture and from shallow (0 to 20 inches) to deep (44 inches) in depth.

Hanover-York Valley

From Hanover to York, Codorus Creek and the West Branch Codorus Creek flow generally along the southeast edge of a long narrow lowland 2 to 4 miles wide formed in steeply dipping and faulted sedimentary rocks of Cambrian and Ordovician Age. The bedrock is largely carbonates (limestone and dolomite) of varying purity and associated shales, sandstone and phyllite.

Because of the extensive folding and faulting of the bedrock, individual formational units tend to be laterally discontinuous. The most extensively exposed unit of the bedrock is the Conestoga limestone, a thin-bedded argellaceous limestone of Ordovician Age.

East of York, the sedimentary rock lowland extends as a narrow valley to Wrightsville but Codorus Creek abandons the lowland at York and turns northward to flow in a narrow, deeply incised valley through the Hellam Hills section south of New Holland.

Soils in the Hanover-York Valley physiographic unit are generally those related primarily to the Cardiff-Whiteford, Hagerstown-Duffield, and the Conestoga-Duffield-Bedford-Lawrence associations. With the exception of the Cardiff-Whiteford association, these soil units are usually found on limestone and calcareous schist bedrock. They are moderately deep to deep and occur mainly on nearly level to moderately sloping land surfaces. Soils produced by weathering of impure carbonates tend to develop silty clay to clay loam "B" horizons which have low permeability.

Slopes in this physiographic subdivision are nearly level to undulating except in an area near Nashville where shale hills rise up to 500 feet above the adjacent carbonate lowlands. There is little dissection because solution openings in the underlying limestone provides well developed subsurface drainage and sinkholes and karst topography has developed.

Southeastern Upland

The part of the basin lying southeast of Codorus Creek and the West Branch Codorus Creek between York and Hanover is within the Southeastern Upland physiographic subdivision. The boundary between this subdivision and the Hanover-York Valley which abuts it on the northwest lies approximately along the line of the Stoner Overthrust.

The Harper Phyllite, the Marburg Schist and the Wissahickon Formation are principal rock units underlying this physiographic unit and they occur in three broad bands aligned subparallel to the Hanover-York Valley.

The Marburg Schist and the Wissahickon Schist are similar in character and can be considered for most purposes as one unit. The Harpers Phyllite and associated Chickies Slate is separated from these older schist units by the Martic Overthrust. Although the Harpers Phyllite occurs locally as outliers on the younger formations to the northwest, the main belt of the Harpers Phyllite occurs between the Stoner Overthrust on the northwest and the Martic Overthrust on the southeast.

Soils of the Southeastern Upland are mainly of the Chester-Elioak-Glenelg and the Glenelg-Manor associations. The principal difference in these two associations is the depth of soil profile development. The Chester-Elioak-Glenelg association have generally deep to moderately deep soils while soils of the Glenelg-Manor association are generally shallow to moderately deep. Both soil associations develop on phyllite or schist but Glenelg-Manor soils occur on moderately sloping to moderately steep topography while the Chester-Elioak-Glenelg soils occupy less hilly topography that is characterized by broad gently rounded ridges. Soils of both associations are characterized by a loam to clay loam texture with silt loam predominant in "B" horizon.

The topography of this physiographic area is steep sloped to rolling with well defined ridge areas. The ridge areas tend to narrow in the higher elevations of the southern extremities of the basin and there is an increase in the proportion of land in excess of 15% slope.

GROUNDWATER CONDITIONS

Water Well Data

Information on 204 water wells within the Codorus Creek Basin were compiled from the records of the Water Resources Division of the U. S. Geological Survey in Harrisburg, Pennsylvania. Data on well depth, casing size and depth, depth to consolidated rock, water level, specific capacity (gpm/ft. drawdown), yield (gpm) and well elevation for individual wells are summarized in Table 1 according to the following geologic units: Wissahickon Formation; Marburg Schist; Harpers Phyllite; Chickies Slate; Antietam Quartzite; Vintage Dolomite; Kinzers Limestone; Ledger Dolomite; Conestoga Limestone. Well numbers given in Table 1 are the field or inventory numbers assigned by the U. S. Geological Survey. There are no records of wells into the Triassic New Oxford Formation within the boundaries of the Basin. Information on the water yielding characteristics of this geologic unit is drawn from a published regional report by Wood and Johnston.[1]

Data on depth to consolidated rock is composited from information presented on casing depth and on depth to bedrock or consolidated rocks given in the well log. Data on specific capacity is reported data and in most instances is derived from a short-term pumping test conducted at the completion of the well.

Regional Relations

New Oxford Formation - According to the report on the New Oxford Formation by Wood and Johnston,[2] groundwater in this geologic unit occurs under both water table and artesian conditions in fractures formed as a result of geologic stresses. The permeability of the bedrock is determined largely by the number, extent, interconnection, shape and size of the crevices.

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[1] Perry R. Wood and Herbert E. Jonston, Hydrology of the New Oxford Formation in Adams and York Counties, Pennsylvania; Penn. Geol. Survey Bulletin 2021, 1964.

[2] Ibid.

TABLE 1

DATA ON U.S.G.S. WATER WELL INVENTORY-
CODORUS CREEK BASIN (as of 7-28-71)
(Source: U.S. Geological Survey)

Well	Total Depth (ft)	Casing & Depth	Depth to Consl. Rock (ft)	Water Level (ft)	Spec. Cap. gpm/ft drawdown	Yield (gpm)	Elevation
Wissahickon Formation							
221	300	-	-	-	-	35	630
222	192	-	-	-	-	100	630
223	800	-	-	-	-	100	630
224	389	8" to -	-	flowing	-	10	810
225	-	8" to -	-	-	-	-	695
227	380	8" to -	-	47.3	7.6	38	882
231	194	8" to 18	-	2.5	4.4	100	830
232	260	8" to 110	-	3	1.1	80	840
233	435	8" to 60	-	25	1.3	110	840
234	350	8" to -	-	62	-	-	885
243	170	8" to 15	-	3.8	.15	20	830
248	100	6 1/4" to 59	-	-	-	15	860
273	110	6" to -	-	3	-	-	780
274	385	8" to -	-	90	.31	17	800
275	200	8" to 20	-	55	2.61	43	800
276	310	8" to -	-	13	1.62	37	805
394	44	6" to 27	-	-	-	10	-
395	80	6" to 20	-	-	-	10	-
398	276	8" to 26	10	60	-	6	-
399	75	6" to 68.5	-	-	-	20	-
400	70	6" to 42	-	-	-	10	-
401	110	6" to 40	-	-	-	5	-
402	140	6" to -	-	4.8	2.06	13	-
403	47	- to 24	-	-	-	15	-
416	200	-	-	24	.79	18	920
417	180	8" to 36	-	56.0	.32	11	940
418	204	8" to -	-	18.4	2.4	43	900
419	220	-	-	51.4	4.8	30	910
439	175	- to 29	-	-	-	.5	-
602	227	4" to 190	-	4	.75	96	-
614	88	6" to 40	-	14.2	-	10	-
616	81	6" to -	-	16.7	.10	5.1	-
618	120	6" to 10-20	-	52.9	.63	7	-
620	220	6" to 12.5	-	60.2	.19	2.4	-
622	65	6"	-	26-87	50	7	-
626	147	6"	-	29	.087	6	-
699	132	6" to 114	-	73	1.13	7	840
701	125	6" to 45	-	61.5	3.4	7	805
Marburg Schist							
214	72	6" to -	-	-	-	-	740
215	-	-	-	-	-	-	745
201	120	6" to 32	27	5.4	.12	6	770
265	145	3 5/8" to 21	19	48	-	3	890
266	160	5 5/8" to 41	37	47	.053	9	910
269	200	6" to 27	24	10	.041	6	865
270	125	6" to 60	54	19	.035	5	795
271	120	6" to 20	12	51	1.21	6	800
272	119	6" to 23	20	46	1.33	9	710
287	100	5 5/8" to 23	20	20	-	8	705
288	41	5 5/8" to 17	-	6	-	10	650
289	120	5 5/8" to 20	3	34	-	7	755
290	160	5 5/8" to 41	39	50	-	7	798
310	100	5 5/8" to 41	37	30	-	10	710
311	160	5 5/8" to 44	40	28	-	2	725
315	200	5 5/8" to 21	14	40	-	1	880
321	180	5 5/8" to 22	7	25	-	1	745
322	98	6" to -	-	24	.26	6	730
396	500	6 1/4" to 13	10	-	-	1	-
397	54	6" to 40	-	-	-	6	-
484	158	- 55	-	-	.08	5	-
603	447	6" to -	-	27	-	-	775
604	130	6" to -	-	-	-	70	-
605	200	6" to -	-	-	-	5	730
606	119	6" to 20	-	-	-	10	-
607	167	6 1/4" to 70	58	35	-	3	740
608	111	6" to -	-	27	1.08	28	-
609	207	6 1/4" to 37	28	33	-	1	700
610	125	8" to -	-	-	-	28	-

TABLE 1 (Cont'd)

Well	Total Depth (ft)	Casing & Depth	Depth to Consl. Rock (ft)	Water Level (ft)	Spec. Cap. gpm/ft. drawdown	Yield (gpm)	Elevation
Marburg Schist(cont'd)							
611	85	5 5/8" to 26	23	18	-	12	545
613	150	6" to 22	21	15	.075	5	580
627	56	6" to 50	-	31	.8	10	760
637	230	6" to 12	10-12	26	-	5	650
639	450	6" to 19	16-18	-	-	4	-
669	150	6 1/4" to 19	17	47	-	4	725
673	310	6" to 30	23	30	-	1	615
675	207	6 1/4" to 51	43	16	-	1	620
677	310	6 1/4" to 38	35	17	-	1	-
679	292	6" to 22	15	20	-	1	-
681	127	6 1/4" to 22	15	-	-	3	610
683	147	6 1/4" to 30	-	38	-	3	750
685	103	6 1/4" to 20	10	37	.15	6	-
691	167	6" to 46	41	26	.36	2.6	645
697	90	6" to 45	-	45	-	-	915
703	122	6" to 35	-	40	.68	10	880
705	115	6" to 14	-	46	2.1	11	865
707	101	6" to 44	-	30	.35	4	840
709	84	6" to 34	-	27	-	10	-
711	102	6" to 20	-	45	-	-	925
713	255	6" to 20	-	38	.25	5	720
715	70	6" to 30	-	10	-	4	650
717	80	5 5/8" to 21	16	30	-	9	-
719	140	5 5/8" to 35	30	50	-	3	990
721	140	6" to -	-	38	-	2	770
723	90	6" to 40	20+	52	2.51	7	890
Harpers Phyllite							
260	117	6" to 20	-	20	.61	33	758
305	165	5 5/8" to 63	60	40	-	3	770
306	100	5 5/8" to 40	35	40	-	9	775
309	140	5 5/8" to 21	16	25	-	5	760
312	105	5 5/8" to 25	20	50	-	9	765
314	120	5 5/8" to 22	9	46	-	5.5	680
317	100	6" to 31	21	15	.31	7	655
319	105	5 5/8" to 21	17	18	-	10	745
320	145	6" to 20	-	-	-	14	743
323	225	5 5/8" to 39	24	60	-	8	780
324	140	5 5/8" to 26	20	30	-	5	745
325	80	5 5/8" to 20	18	9	-	6	675
326	190	5 5/8" to 21	17	39	-	1.5	725
327	43	6" to -	-	9	.22	5.2	510
328	103	6" to 30	36	30	-	20	520
329	80	5 5/8" to 41	37	30	-	10	685
333	117	5 5/8" to 30	15	60	.11	6	690
334	140	5 5/8" to 61	58	50	-	6	705
336	100	5 5/8" to 40	35	50	-	10	782
339	100	5 5/8" to 25	20	35	-	10	647
340	120	5 5/8" to 22	16	12	-	5	660
346	63	6" to 20	8	13	-	15	585
353	205	6" to 68	60	55	-	1.5	655
354	250	6" to 50	-	16	.16	8	610
367	100	6" to 16	17	43	.89	6	680
368	100	5 5/8" to 32	30	21	-	100	685
369	100	5 5/8" to 22	15	50	-	10	687
374	120	6 1/4" to 45	38	44	-	6	655
377	84	6 1/4" to 31	28	43	-	25	-
378	140	6 1/4" to 26	21	30	-	5	605
379	127	6 1/4" to 29	-	29	-	3	580
386	228	6 1/4" to 40	35	40	-	6	620
387	105	6 1/4" to 30	18	30	-	12	600
388	180	6 1/4" to 26	20	28	-	15	605
389	110	6 1/4" to 31	27	42	-	8	650
391	82	6 1/4" to 26	19	29	.36	15	640
601	174	6" to 45	43	55	-	16	700
615	27	-	-	8.3	-	-	595
617	110	6" to -	-	18	.11	4.2	630

TABLE 1 (Cont'd)

Well	Total Depth (ft)	Casing & Depth	Depth to Consl. Rock (ft)	Water Level (ft)	Spec. Cap. gpm/ft. drawdown	Yield (gpm)	Elevation
Harpers Phyllite (cont'd)							
619	105	6 1/4" to 28	20	15	-	40	625
621	150	6" to -	-	19.6	-	-	-
661	248	6 1/4" to 23	12	100	-	3	590
663	170	6 1/4" to 19	6	24	-	1	-
665	127	6 1/4" to 21	12	19	.64	7	600
674	215	6" to -	-	41	.029	3.5	-
686	164	6" to 26	-	8	.084	10	-
728	200	6" to 45	-	21	.87	29	690
764	150	6" to 28	10	20	.1	13	-
771	207	6 1/4" to 29	12	35	.11	7	480
788	112	6" to 12	-	44	.4	4	440
Chickies Slate							
210	90	6" to -	-	80.1	1.02	4.2	780
332	125	5 5/8 to 38	35	30	-	9	770
342	125	6" to 68	50	22	-	14	800
343	57	6" to -	-	17.4	780.0	7.8	955
351	110	6" to 30	-	50	-	15+	785
352	94	6" to -	-	34.7	.044	4	715
363	327	6" to -	-	8.9	.18	13.5	515
371	100	6 1/4" to 30	24	43	-	20+	-
372	54	6 1/4" to 29	12	9	.6	8	690
373	136	6 1/4" to 67	61	51	.095	4.3	865
376	207	6 1/4" to 41	38	25.3	.05	3	745
392	147	6 1/4" to 43	-	44	-	7	830
Ledger Dolomite							
77	312	8" to 150	-	-	.60	89	405
79	125	6 1/4" to 16	9	13.4	15.3	60	410
242	300	8" to 11	-	20	.27	15	413
385	100	6 1/4" to 18	7	9	-	15	440
361	624	10" to -	-	14	.75	164	445
362	45	6" to -	-	4.8	5.5	9.5	455
547	18	- to 15	-	6	10.3	65	385
726	252	8" to -	-	22	6.3	390	395
727	298	10" to -	-	20	18.0	800	395
Antietam Quartzite							
623	85	5 5/8" to 56	50	25	-	12	-
Troshe	94	6" to 86	-	28	5.3	25	650
355	97	6" to 40	-	25.6	.17	5	520
331	100	5 5/8" to 41	35	50	-	12	590
612	125	- to 40-60	-	43	2.6	4.3	-
Vintage Limestone							
344	100	70	69	42	-	20+	520
345	73	38	33	30	3.3	30	500
364	830	-	-	-	-	300	505
365	65	-	-	-	.09	-	-
366	51	15	-	10	.91	6.7	475
786	400	60	-	12.5	.035	5	335
805	50	-	-	25	-	-	418
Kinzers Limestone							
76	230	6" to 150	-	58.6	.073	7.7	440
283	510	6" to -	-	10	.54	111	595
284	75	6" to -	-	15	-	18	595
285	163	6" to -	-	10	-	20	590
318	150	6" to 20	20	16.25	.09	9	635
318	233	6" to 35	-	26	-	-	663
341	50	6 1/4" to 38	36	7	.52	20+	480
347	195	5 5/8" to 81	74	70	-	2	505
348	70	6" to 46	43	15	-	20	510
380	-	-	-	-	-	-	-
381	69	6" to 55	52	30	-	20	-
384	-	-	-	-	-	-	-
767	65	6" to -	-	51	.49	4.5	480
769	135	6" to -	-	36	.066	-	445

TABLE 1 (Cont'd)

Well	Total Depth (ft)	Casing & Depth	Depth to Consl. Rock (ft)	Water Level (ft)	Spec. Cap. gpm/ft. drawdown	Yield (gpm)	Elevation
Conestoga Limestone							
95	122	6" to -	-	20	1.76	75	370
96	160	6" to -	-	11.5	.69	35	360
208	238	6" to -	-	11	-	23	355
241	408	8" to 28	-	19.7	3.0	24	430
277	100	6" to 20	-	5.4	.42	30	542
278	298	8" to 23	-	10	.59	68	565
279	350+	8" to -	-	-	Dry	Dry	565
280	350+	8" to -	-	10	.05	15	565
330	40	5 5/8" to 33	30	12	-	20	583
546	127	8" to -	-	20	13.32	63.5	400
625	135	6 1/4" to 19	15	12	-	30	515
631	300	6" to 46	-	22	1.05	17.4	480
633	38	6 1/4" to 36	28	6	12.7	100	465
671	208	6 1/4" to 17	8	8	-	2+	470
729	742	8" to 23	-	10	.14	40	-

The depth of wells in the New Oxford Formation in Adams and York counties range from 31 to 1,005 feet and average about 150 feet. Sixty percent of the wells range in depth from 75 to 150 feet and only about 20 percent are deeper than 150 feet. Well yields range from less than 1 gpm to 200 gpm. Frequency analysis of yields show that 70 percent of the wells yield 10 gpm or less and only about 15 percent yield more than 20 gpm.

Specific capacity (the ratio of the yield of a well in gallons per minute to its drawndown in feet,) for wells in the New Oxford Formation range from 0.05 to 6.50 in York County[1] and average 0.67. An analysis of controlled pumping tests of 60 minute duration indicates that 84 percent of the wells tested have specific capacities that range from less than 0.1 to 0.6 gpm per feet of drawdown and average about 0.2 gpm per ft.[2].

Other Basin Units - Descriptive information on groundwater conditions in the New Oxford Formation relate to the other geologic units within the Codorus Creek Basin in many respects. All bedrock units within the basin transmit water as a consequence of the jointing and fracturing of the rock. The permeability of most of these units, as in the case of the New Oxford Formation, is the result of the number, extent, interconnection, shape and size of the crevices. In limestone and dolomite formations, however, joints and fractures are likely to be enlarged by solution action and, locally, greater ranges in yield and higher well productivity result.

The movement of groundwater is from points of recharge in the interstream areas to points of discharge along the valleys and streams. The pattern of flow is in angular paths along fractures and there is a characteristic decrease in permeability with depth in such units.

According to the data developed in Table 2, the highest specific capacity and well yields are obtained from the Ledger Dolomite, the Wissahickon Formation, the Conestoga Limestone and the Antietam Quartzite. Date from the Antietam Quartzite is, however, extremely limited and may not be representative of this formation. The Harpers Phyllite, Chickies Slate and Kinzers Dolomite have specific capacities consistently less than 1 gpm per ft. drawdown suggestive of lower transmissivity for these bedrock units.

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[1] Ibid, Table 6.

[2] Ibid, p. 24.

TABLE 2

WELL DEPTH, DEPTH TO CONSOLIDATED ROCK AND SPECIFIC CAPACITY BY FORMATIONAL UNIT IN CODORUS CREEK BASIN
(Based on U.S. Geological Survey water well inventory data)

Formation	Total Depth of Well			Depth to Consolidated Rock (Based on Casing Depth & Drillers Log)			Specific Capacity (gpm/ft. drawdown)		
	Mean	Range	No. of Readings	Mean	Range	No. of Readings	Mean	Range	No. of Readings
Wissahickon Formation	205	44-800	37	39	13-150	20	4.10	.087-7.60	21
Marburg Schist	159	41-500	54	25	7-58	46	0.64	.035-2.51	18
Harpers Phyllite	137	27-250	50	24	6-60	40	0.35	.029-0.89	14
Chickies Slate	131	54-327	12	35	12-61	8	0.33	.044-1.02	6
Antietam Quartzite	100	85-125	5	47	35-70	5	2.69	0.17-5.30	3
Vintage Dolomite	224	50-830	7	42	10-69	4	1.08	.035-33.0	4
Kinzers Limestone	162	50-510	12	44	20-74	7	0.30	.066-0.54	6
Ledger Dolomite	230	18-624	9	8	6-10	4	7.13	0.27-18.0	8
Conestoga Limestone	241	38-742	15	22	8-30	9	3.07	0.05-13.32	10

The broad range in specific capacity for most of the geologic units is indicative of broad range in permeability within the rock unit. Variability in yields within short lateral distances is characteristic of rock units with fracture permeability.

Table 3 gives pertinent data from water wells in the Spring Grove, Hanover and Glen Rock site study areas. Data on wells in the Harpers Phyllite near Spring Grove are similar to those obtained for the Phyllite throughout the basin. At the Hanover site study area (Conestoga Limestone) and the Glen Rock site study area (Wissahickon Schist) however, specific capacities are somewhat lower than the basin average for the geologic unit.

SITE AREA INVESTIGATIONS

Procedures of Investigation

The Codorus Creek Basin is a complex area composed of several geologic terrains. Sites for investigation were selected on the basis of utility of the area for wastewater application operations and areas representative of major terrainal elements and topographic settings (Figure 3). Individual investigation points were delineated to determine textural and depth variations within the solum, depth of rock, weathering, and permeabilities of the earth materials.

An important input to site selection was that of soil type. Soils that had been identified as having more rapid permeability and significant areal extent were generally selected for testing because these soils were expected to be more amenable to land application techniques.

The site areas were investigated by a reconnaissance drilling program conducted by the Corps of Engineers that was designed to provide data on the types and thicknesses of materials encountered, obtain samples of materials for laboratory testing and analysis, and determine permeability relationships. The extent of the investigation was severely limited by time and availability of funds so that emphasis was placed on obtaining representative data on terrainal elements rather than detailed analysis of individual site areas.

Soils were sampled by a standard penetration test using a 2-inch OD split tube sampler driven by a 140 pound hammer dropped 30 inches. The number of blows to drive the sampler was recorded for

TABLE 3

WATER WELL DATA IN THE SPRING GROVE, HANOVER AND GLEN ROCK STUDY AREAS
(Source: U. S. Geological Survey)

Well	Total Depth (ft)	Casing & Depth	Depth to Consl. Rock (ft)	Water Level (ft)	Spec. Cap. gpm/ft. drawdown	Yield (gpm)	Elevation
A. HARPERS PHYLLITE @ SPRING GROVE							
771	207	6 1/4" to 29	12	35	.11	7	480
686	164	6" to 26	-	8	.084	10	
387	105	6 1/4" to 30	18	30		12	600
386	228	6 1/4" to 40	35	40		6	620
379	127	6 1/4" to 29	-	29		3	580
377	84	6 1/4" to 31	28	43	-	25	-
388	180	6 1/4" to 26	20	28	-	15	605
374	120	6 1/4" to 45	38	44	-	25	-
375	-	-			-	-	-
389	110	6 1/4" to 31	27	42	-	8	650
390	-	-	-	-	-	-	-
369	100	5 5/8" to 20	15	50	-	10	687
368	100	5 5/8" to 32	30	21	-	100	685
367	100	6" to 16	17	43	.89	6	680
370	-	-	-	-	-	-	-
601	174	6" to 45	43	55	-	16	700
617	110	6" to -	-	18	.11	4.2	630
B. CONESTOGA LIMESTONE @ HANOVER							
330	40	5 5/8" to 33	30	12	-	20	583
277	100	6" to 20	-	5.4	.42	30	542
279	350+	8" to -	-	-	Dry	-	565
278	298	8" to 23	-	10	.59	68	565
280	350+	8" to -	-	10	.05	15	565
285	-	-	-	-	-	-	-
316	-	-	-	-	-	-	-
318	-						
C. WISSAHICKON FORMATION @ GLEN ROCK							
275	200	8" to 20	-	55	2.61	43	800
276	310	8" to -	-	13	1.62	37	805
274	385	8" to -	-	90	.31	17	800
419	220	-	-	51.4	4.8	43	900
410	200	-	-	24	.79	18	920
602	227	4" to 190	-	4	.75	96	-
620	220	6" to 12.5	-	60.2	.19	2.4	-

each 0.5 foot drive interval to obtain both an estimate of the relative density of the soil samples for identification and analysis by the laboratory. Logs and infiltration data from individual borings are provided in Appendix A.

Rock cores were taken to determine the type of lithology, its stage of weathering, the extent to which it was fractured and broken, and the type and extent of water movement through its fractures and cavities. The test holes were continued into relatively fresh rock.

Bore hole permeability testing was carried out in both soil and rock materials. The split tube sampler hole was used to conduct constant head permeability tests over a 15-30 minute time interval. The soils encountered in the profile were generally fine-grained and very little water entered the soil during this short test interval. Large diameter auger holes were also placed in the soil adjacent to the test hole and longer term (8-hour) infiltration tests ran at various depths in the soil profile (See Appendix B for percolation test data). Tests in the weathered and decomposed rock and saprolite were conduced in the bore holes until firm rock (hard enough to be cored) was reached. The permeability of rock units was estimated through the use of pumping-in pressure tests using pneumatic packers to isolate test intervals within the hole.

An attempt was made to apply as little pressure on the holes as possible to simulate the low heads associated with an irrigation system. Open hole permeability tests were used to provide data in areas of very weathered rock where the rock was not competent to hold a seal with the packers.

Soil samples obtained during the standard penetration test were logged in the field by soil engineers, and then sent to the Corps of Engineers' soils laboratory for examination and analysis. Soil characterization of representative samples by the laboratory using the Unified Soil Classification System are given in Appendix C-1. All samples were visually examined and classified using the Unified Soil Classification System by technicians of the Corps of Engineers Soil Laboratory.

Rock cores were logged and described in the field and boxed for storage away from the site. These cores were then examined by engineering geologists and relogged in detail. The core logs stressed not only the lithologic description of the rocks and their dominant

mineralogy but also the amount and types of jointing and fracturing, the type and extent of weathering and decomposition, the relative hardness of the rock and the implicit permeability characteristics including, observed evidence of water movement through them, and the rock structure and fabric related to water movement or permeability.

Permeability rates from tests in both the soil and rock were computed from the field test data using the following equations which are derived from the formula[1]

$K = Q/5.5\ rh$ where K = permeability in feet per day

Q = water intake in gallons per min.

h = head in feet

r = radius of the test hole in feet

In order to accommodate the various cross-sectional areas of the drill or auger holes, the following equations[2] were used:

Where the length of the test section is more than or equal to five times the diameter of the test hole, the equation

$$K = \frac{30.6\ Q}{Lh} \log_e \left(\frac{L}{r}\right)$$ was used, where

K = permeability in feet per day

Q = water intake in gallons per min.

L = length of test section in feet

h = head in feet

r = radius of the test hole in feet

Where the length of the test section is less than five times the diameter of the test hole, the equation $K = \frac{30.6\ Q}{Lh} \sinh^{-1} \left(\frac{L}{2r}\right)$ was used. These

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[1] Earth Manual, U.S.B.R., Appendix E-18 (1960).

[2] Soil Conservation Service, National Engineering Handbook, Section 8, Chapter 2.

forms of the equation are particularly convenient as they use the measurement units determined in the field. Permeabilities computed from pressure testing data used the same equations with the gage pressure converted to feet of head (1 psi = 2.31 feet).

Water intake in bore holes in the soil profile tended to be low due to the very fine-grained soils encountered and the disruption of soil structure by sampler penetration. Permeability tests taken in bore holes were short-term tests and to provide better data on soil permeabilities, additional auger holes were placed at varying depths in the soil profile and longer term percolation tests performed. These holes were larger with a greater cross-sectional area and provided saturated permeability rates. However, these reates must also be considered as short-term tests and not definitive of permeability conditions of extended saturation. Care was taken in excavating the test holes to minimize damage to soil structure. Locations of these holes are shown on maps of the test locations in the report. Generally three to four, 6 to 8 inch diameter holes were placed in each site at depths of 1, 2, 3, and 4 feet. The bottom foot of each hole was tested and the intake of water per unit of time noted during the length of the test. Results of this data are summarized in Table 4.

Shallow refraction seismic studies were performed by geologists of the Corps of Engineers using a multiple trace engineering seismograph. These studies used drill holes as interpretive references to extend soil-rock profile information to adjacent areas. These seismic stations were located in such a manner as to provide data about differences in the thickness of solum, depth of weathering, relief on the rock surface, effect of topography on the weathering depth, and the presence of cavities. Results of the studies are given in Appendix C-2.

Site Area Studies

Site Area 1 - Spring Grove - Site investigations involving four subsurface borings, four soil profile permeability tests and geophysical profile studies were conducted in the upland region south of West Branch Codorus Creek along highways 66007 and 516 east and south of Spring Grove and southwest of Stoverstown (Figures 3,4). The Harpers Phyllite is the underlying bedrock and the soils investigated

TABLE 4

SUMMARY OF LONG-TERM PERMEABILITY TESTS

Site Area	Test Site/Soil	Hole Diam. (inches)	Depth (ft)	Interval (ft)	K (ft/day)
Spring Grove	1	6"	1.5	0.0-1.5	5.65
			3	2.0-3.0	0.22
	Manor		3	2.0-3.0	0.16
			3.5	2.5-3.5	0.07
			1.0	0.7-1.0	0.94
	2	6"		0.6-1.0	1.43
	Manor		3.0	1.5-3.0	0.02
			4.0	1.9-4.0	0.007
			1.0	0.5-1.0	3.19
	3	6"	3.0	1.9-3.0	0.09
				1.9-3.0	0.05
	Chester		4.0	3.0-4.0	1.1
				2.8-4.0	0.1
			2.0	1.0-2.0	0.37
	4	6"		1.5-2.0	0.50
			3.0	2.0-3.0	0.29
				2.1-3.0	0.73
	Chester		4.0	3.0-4.0	0.22
				3.2-4.0	0.57
Hanover			1.0	0.0-1.0	0.6
	1	5"	3.0	2.0-3.0	0.014
	Conestoga		4.8	3.3-4.8	0.006
	2		1.0	0.0-1.0	0.84
	Conestoga	5"	2.0	1.0-2.0	2.3
		6"	3.0	2.0-3.0	0.06
	3	6"	1.0	0.0-1.0	0.84
	Conestoga			1.9-2.9	0.015
			4.0	3.0-4.0	0.09
	4	6"	2.0	1.0-2.0	0.75
	Conestoga		3.0	2.0-3.0	0.055
			4.0	3.0-4.0	0.3
			1.0	2.0-1.0	0.54
	5	6"	2.0	1.0-2.0	0.09
	Conestoga		3.0	2.0-3.0	0.21
			4.0	3.0-4.0	0.09
Glen Rock	1	6"	2.0	1.0-2.0	1.4
	Chester		3.0	2.0-3.0	0.6
			4.0	3.0-4.0	0.4
			2.0	1.0-2.0	1.5
	2	6"	3.0	2.0-3.0	3.6
	Chester		3.5	2.5-3.5	0.1
	3	8"	1.5	0.5-1.5	0.6
	Chester	6"	3.0	2.0-3.0	7.5
			3.5	2.5-3.5	0.03
	4	6"	2.0	1.0-2.0	0.9
	Chester		3.0	2.0-3.0	0.5
			4.0	3.0-4.0	0.5
	5	8"	1.0	0.0-1.0	50+
Bair	Cardiff		3.0	2.0-3.0	0.08
		6"	4.0	3.0-4.0	2.70
	6		1.5	0.5-1.5	50+
	Cardiff	6"	2.0	1.0-2.0	0.5
			3.0	2.0-3.0	0.06

were the Chester and Manor soil series. The soil profile characteristics established in this site area study are considered to be representative of those that generally prevail for Chester and Manor soil occurrences on the Harpers Phyllite.

Correlations of physical characteristics with depth (Figure 5) establishes the existence of four sequential profile elements and their distribution among the four control borings. The uppermost zone of the profile is the soil zone which extends to depths of 3 to 6 feet below land surface. The lower part of this zone is denser and more compact than the upper surficial layer. The second zone of the profile is the weathered phase of the phyllite bedrock (saprolite) in which the indurated character of the bedrock has been completely altered to that of the soil although relics of bedrock structure can still be seen when closely examined. This zone extends to depths of 10 to 15 feet in the area of the Chester soil but is not present at boring site 1 within the Manor soil. The third zone of the profile is that of very weathered phyllite with a strong fracture and joint pattern which extends from 8 to 30 feet below land surface. The fourth zone is the zone of moderately to slightly weathered phyllite which is too indurated to be penetrated by the soil sampler. This zone grades gradually to unweathered phyllite at depth. The lithologic, structural and permeability characteristics of these zones within the profile are shown in a summary log in Figure 5.

Permeability data acquired during the course of the investigations indicate that the overall permeability of the profile is (less than 20 feet per day) with marked differences in permeability among the individual zones. The lowest permeabilities are in the basal part of the upper zone and average about 0.3 ft. per day. No major differences in soil-bedrock profile characteristics between areas underlain by the Manor and Chester soils were noted. The highest permeabilities occur in zone four where rates ranging from .02 to 17.6 ft. per day were obtained. The bore hole data gave an average permeability for this zone of 1.95 ft. per day but regional indications are that overall permeability of the bedrock decreases with depth.

Depth to groundwater saturation in bore holes varies within the site area depending on the topographic position of the boring site. At bore holes 2 and 4 groundwater levels are deeper than 30 feet, indicating that groundwater gradients are signficantly less than land surface gradients. The transmissivity of the bedrock, therefore, appears to be adequate to transmit the quantity of water presently reaching the saturated zone without resulting in saturation of the soil-bedrock profile.

Land slopes in the site area range from moderately steep to gentle and much of the area has slopes of 8 percent or less. Relief is pronounced and elevations range from nearly 900 feet on the higher levels of the upland to less than 500 feet in the valley of West Branch Codorus Creek within a horizontal distance of about 2 miles. Drainage of the surface is well integrated.

Site Area 2 - Hanover - Site investigations involving six subsurface borings, six soil profile permeability tests and geophysical profile studies were conducted in the level upland areas east and northeast of Hanover (Figures 3,7). The bedrock of the area is the Conestoga limestone and the major soil series is the Conestoga silt loam. Profile characteristics established in this site area study are considered to be representative of the Conestoga terrain where it constitutes a broad upland surface without signfiicant relief.

Four profile elements are recognized within the soil-bedrock profile and were present in all borings (Figure 8). The uppermost zone extends from 4.5 to 13.5 feet below land surface and is composed of silty and sandy clay with a few gravel size rock fragments. The second zone is a highly weathered saprolite consisting of silty clay, silty clayey sand and weathered shale extending to depths of 11 to 34 feet at the boring locations. A somewhat less weathered but decomposed zone of limestone and shale underlies the saprolite zone and forms a sharp contact with indurated limestone and shale of the bedrock. The lithologic, structural and permeability characteristics of these zones within the profile are shown in a summary log in Figure 9. The depth to fresh bedrock is quite variable and the presence of rock pinnacles were indicated in both the drilling results (17.2 to 44.1 feet) and the analysis of the seismic data (10 to 42 feet).

Permeability data acquired during the site area investigation show that the permeability characteristics of the upper two zones of the profile are extremely low ranging from about .004 ft per day to 2.3 ft per day. The lower two zones are somewhat higher in permeability, locally exceeding 50 feet per day in zone 3 and ranging up to 15 per day in zone 4, the unweathered bedrock. The lowest permeabilities are those occurring in the basal part of the upper zone where the average permeability is that of zone 3 at 25 ft. per day but with a broad range in permeability of .01 to 50+ ft. per day.

Specific capacity data from wells in the site area indicate that no definite pattern with depth can be determined and a relatively broad range in yield can be anticipated due to the jointed and fractured character of the bedrock, depths to groundwater is generally

shallow, (within 20 feet of land surface) indicating that groundwater gradients are not significantly different than land surface gradients within the site area and that the physical opportunity to greatly increase the head differential on the groundwater system is limited.

Slopes in the site area range from level to moderately sloping with most of the area of a slope of less than 8 percent and a large part is within slopes of 3 percent. Relief is moderate to low ranging from an elevation of about 600 feet along the western edge of site area to an elevation of about 520 at Oil Creek at the eastern edge of the site area over a distance of 1.5 to 2 miles.

Site Area 3 - Glen Rock - Site investigations involved four subsurface borings, four soil profile permeability tests and refraction seismic studies conducted in an upland region east and southeast of Glen Rock near Shrewsbury (Figures 3,10). The underlying bedrock is the Wissahickon schist and the soil tested was the Chester silt loam.

Four profile elements were identified and correlated within the study area (Figure 11). The uppermost zone of the profile extends to depths of 6 to 9 feet below land surface and is composed of sandy and clayey silts and silty clays. The second zone of the profile is a very weathered and soft muscovite schist with joints that show signs of water movement along these paths. The zone of very weathered schist ranges to depths of 10 to 18 feet below land surface.

The third zone is a moderately weathered schist that is slightly broken with a well defined joint pattern. The moderately weathered schist extends to depths between 18 and 30 feet below land surface.

The fourth zone is the slightly weathered schist which grades gradually into unweathered schist with depth. The lithologic, structural and permeability characteristics of these zones within the profile is summarized in log form on Figure 12.

Permeability data indicate that the overall permeability of the profile is somewhat higher than that obtained in the Spring Grove area which is underlain by phyllite. The least permeable part of the profile is the lower part of the upper zone where permeabilities range from .01 to 0.7 ft. per day and average about 0.5 ft. per day in short-term tests. Highest permeabilities (up to 80 ft. per day) were obtained in the very weathered schist (zone 2) however, this

zone has a broad range of permeabilities extending from 0.17 to 80 ft. per day. The permeability of the lower two zones of the profile is similar and intermediate in value between that of the uppermost zone and the second zone. Specific capacity data from wells in the Wissahickon schist (Tables 1, 2) suggests that the permeability of the bedrock is likely to be somewhat larger than in the area underlain by phyllite even though the average permeability of the upper bedrock obtained in the soil borings is similar in both areas.

Groundwater was not reached in three of the four bore holes indicating that the level of groundwater saturation is deep under the upland ridges. One boring encountered water at a depth of 29.5 feet. The deep level of saturation is believed to be a consequence of the slightly higher permeability of the bedrock and consequence of the deep dissection that characterizes the study area.

Land slopes range from moderately sloping to steep. Over much of the area slopes are in excess of 8 percent and only the relatively narrow ridge lines have significant areas with less than an 8 percent slope. Relief is very pronounced and ranges from an elevation of about 1,000 feet on the ridge line to an elevation of about 700 feet in the valley of Trout River.

Site Area 4 - Dover - Subsurface investigations at the Dover area are incomplete owing to the expiration of time and drilling funds. Only two of the four proposed drilling sites were drilled and tested and no soil profile permeability tests were made in this site area. The two drill holes completed were those located on shale beds in the New Oxford Formation of Triassic Age. Drilling was not conducted at locations proposed to determine the characteristics of the associated sandstone beds which underlies most of the site. Location of the site southwest of Dover is shown on Figure 3 and 13. Results of the drilling are correlated and summarized in Figures 14 and 15. The drilling program disclosed that there is a shallow zone of silty clay and clay silty sand soil developed on the shale beds. Similar conditions of shallow soil development are also expected for the sandstone units.

Land slopes within the site area range from nearly level to moderately steep and the bulk of the area has slopes of less than 8 percent. Relief is low to moderate and land surface elevations range from about 560 feet on the upland to about 400 feet along Paradise Creek in the southeast part of the site area over a distance of about 1 mile.

Site Area 5 - Bair - The site investigations included two subsurface borings, two soil permeability tests and refraction seismic studies in the upland region in the vicinity of Bair (Figures 3 and 16). The bedrock underlying the boring sites is the Conestoga limestone and the drilling was undertaken to establish the characteristics of this geologic unit in a region of more pronounced relief than is the case at Hanover. If significant differences between the two areas would be observed, the conditions at the Bair site would be more relevant to the Conestoga limestone terrain at other locations within the Hanover-York Valley physiographic unit. The results of the data acquired is shown in Figure 17. The soil profile and permeability characteristics are similar for the two areas. The only significant variations are the indication of limestone at very shallow depth locally within the Bair area and the greater depth to groundwater at Bair as compared to the Hanover area. The increased depth to groundwater is a consequence of the greater relief in the Bair area. The shallow depth to bedrock indicates that pinnacles on the bedrocl surface can be anticipated in the Conestoga limestone.

The data on soil profile characteristics were obtained on Cardiff slaty silt loam, a soil type commonly occurring in the mixed bedrock terrain. The data indicate that the permeability characteristics of this soil at a depth of three feet is similar to that of the lower part of the upper zone in Chester and Manor soils.

RELATIONS OF PHYSICAL CHARACTERISTICS TO WASTEWATER APPLICATIONS

Significance of Physical Characteristics

All soils investigated within the Codorus Creek Basin in regions considered for wastewater application have well defined soil profile development. An essential characteristic of this profile development is the presence of a zone of relatively low permeability (generally the B Horizon) overlain and underlain by zones of somewhat higher permeability. In the geologic profiles given for each of the site areas investigated, this layer of low permeability occurs within the uppermost zone of the profile. The thickness of the low permeable zone is variable but ranges up to 10 feet. Commonly, this zone is more than 2 or 3 feet thick and is present to depths of two to six feet below land surface.

The zone of lowest permeability is the primary determinant of the rate at which fluids can infiltrate from land surface to deeper lying levels. Determinations of application rates of wastewater must take into consideration the permeability characteristics of this intermediate zone within the application area. Soil permeability determinations based on short-term infiltration tests might not be representative of permeability rates that prevail under wastewater application operating conditions involving spray application. It is important to note that infiltration rates significantly lower than those observed under short-term infiltration test could prevail under conditions of continuous saturation[1,2] and that infiltration and permeability characteristics of the soil is affected by a variety of environmental factors that are associated with irrigation practices[3,4,5].

Throughout most of the Codorus Creek Basin, extensive areas of relatively thick soil developments can be identified. Provided these areas have adequate infiltration capacity, the thickness of the soil column is beneficial to the polishing of the infiltrating wastewater. In the area of the Triassic bedrock, however, soil development is characteristically thin - 3 feet or less - and the polishing function of the soil is significantly inhibited.

Permeability by virtue of joints, fractures and the enlargement of these by solutioning and weathering is the dominant characteristics of subsurface units in the Codorus Creek Basin. Conditions of intergranular permeability occur only in alluvial deposits, basin fills and in the soil produced by weathering of the indurated bedrock. These materials are generally fine-grained, restricted in occurrence or lie well above the level of groundwater saturation. No extensive areas

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[1] Bodman, G. B, The Variability of the Permeability Constant at Low Hydraulic Gradients During Saturated Flow in Soils; Soil Sci. Soc. Amer Proceedings 2, p. 45-53, 1938.

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of intergranular deposits of high permeability suitable for land application projects are known to exist in the basin.

The transmissivity (permeability times thickness) characteristics of the subsurface is dependent on the distribution, concentration, orientation and depth of secondary linear openings in the indurated bedrock. Information acquired in the drilling program and from specific capacity data on water wells within the basin indicate that there is a wide range in permeability characteristics within each of the geologic units, that the average level of permeability is in the order of magnitude of one to tens of gallons per day per $ft.^2$ and that the zone of highest permeability is generally restricted to the upper few hundred feet of bedrock.

These characteristics serve to complicate the design of effective subsurface drainage control systems in that analytical techniques for prediction of local groundwater flow paths and transmissivity characteristics are likely to be limited as a predictive tool and that these characteristics probably will have to be determined on an empirical basis at each application site. A further complication to effective drainage control is in the area of the Triassic bedrock where, as a consequence of bedding, hydrologic interconnection from land surface to deeper lying permeable units is likely to be interrupted or severely restricted by intervening beds of low permeability.

Slope conditions within the drainage basin serve to limit the amount of area suited to land application in that a significant proportion of the basin area is at slopes greater than 15 percent. Slopes are generally uniform, however, and as a consequence the areas of gentler slopes tend to form broad continuous bands bordered by the areas of steeper slope. Areas of moderate to gentle slope mainly along the upland drainage divides in the schist and phyllite terrains and on surfaces of the carbonate formations and the Triassic bedrock.

Due to the high relief for most of the basin area, groundwater saturation lies at depths in excess of 20 feet under most of the upland areas. One exception is the low lying upland area at Hanover where, because of the low regional relief, groundwater levels are commonly within 10 feet of land surface.

Terrainal Units Relevant to Wastewater Application

On the basis of differences in type and nature of underlying bedrock, slope, relief and degree of dissection of the land surface, soil type and profile characteristics, transmissibility of bedrock units and depth to groundwater saturation, the Codorus Creek Basin is subdivided into five terrainal units relevant to wastewater application considerations as follows: (1) the Schist Terrain; (2) the Phyllite Terrain; (3) the Conestoga limestone terrain; (4) the Triassic sandstone-shale terrain; (5) the mixed bedrock terrain. The distribution of these terrainal areas within Codorus Creek basin is shown on Figure 2.

The primary basis for definition of the terrainal units is the type and characteristics of the underlying bedrock which is a determinant of the soil, topographic and hydrologic characteristics. Within the terrainal unit, variations in soil texture and soil profile characteristics, transmissibility characteristics, slope conditions, depth to groundwater saturation and topographic position provide the basis for subdivision of the individual terrainal unit into various management areas.

Schist Terrain - The Schist Terrain is that portion of the basin southeast of the Martic Overthrust line. Potentially large differences in bedrock transmissivity between the Marburg Schist and the Wissahickon Formation geologic units indicates that the schist terrain can be separated into the Marburg subunit and the Wissahickon subunit on the basis of available specific capacity data (Table 2). Whether these differences are sufficiently great and persistent enough to justify considering the two subunits as major terrainal units can only be substantiated by more detailed hydrogeologic investigations within the two geologic units.

Soil-slope relationships for the terrainal areas are provided by detailed soil mapping conducted by the U. S. Department of Agriculture, Soil Conservation Service.[1] The two principal soil associations within the schist terrain are the Chester-Elioak-Glenelg association and the Glenelg-Manor association. The Chester and Elioak silt loams are well-drained soils and occur on nearly level to moderately sloping surfaces. The Glenelg silt loam is moderately deep, well drained and generally occurs on moderate slopes. The topography of the Glenelg-Manor association is hilly and is characterized by long slopes and moderately broad ridges.

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[1]Donald M. Hersh, Soil Survey of York County, Pennsylvania, U.S. Department of Agriculture, Soil Conservation Service Series 1959 No. 23, 1963.

Soils within the schist terrain can be grouped into three broad slope categories for each of the two associations; (a) 0-8 percent slope range; (b) the 8-15 percent slope range, and (c) in excess of 15 percent slope. Soil map units presented in York County soil report within each of these categories are given in Table 5. The map symbol identifies the soil series (Ch, Ek, Ge, M), slope class (A, B, C, D, etc.) and the severity of erosion (2 or 3).

Grouping of soil mapping units according to these soil-slope categories provides a basis for determining the areal distribution of soil conditions most suited to land application of wastewater and of the dimension of potential application areas as determined by topographic conditions. Most suitable are the areas of deep well drained soils (Chester and Elioak) on slopes not exceeding 8 percent (A category). Soils occurring on slopes of 8 to 15 percent (B category) are likely to have greater limitations and those areas where slopes in excess of 15 percent exist (C category) are severely limited by slope and erosion factors. In addition, land areas occurring in the bottomlands of the narrow drainage valleys should be excluded from consideration because of the restricted areal extent and because of the liklihood for shallow depth to groundwater saturation. Soil texture and slope conditions most suited for land application are widespread within the Schist Terrain but the lateral extent of these areas is more restricted than in other terrainal areas because of the relatively deep dissection of this high lying region.

Phyllite Terrain - The Phyllite Terrain lies between the Martic Overthrust on the southeast and the Stoner Overthrust on the northwest. Included with the Harpers Phyllite which is the predominant bedrock are the Chickies Slate and the Antietam Quartzite. On the basis of specific capacity data, productivity of bedrock wells appear to be lower in this terrain than in the Schist Terrain which could require closer spacing of drainage control facilties.

Soil-slope relationships within the Phyllite terrainal area are similar to those described for the Schist Terrain - (see Table 5 for soil mapping unit categories). Topographically, the Phyllite Terrain is less rugged than the adjacent Schist Terrain. Consequently, the ridge areas are somewhat broader and more gently sloping and the extent of contiguous area of most satisfactory slope conditions are likely to be greater in extent.

TABLE 5

CATEGORIES OF SOIL MAPPING UNITS IN THE SCHIST AND PHYLLITE TERRAINS

I. Chester-Elioak-Glenelg Association

0-8% Slope		Soil Mapping Units
A.	(moderate erosion)	Ch A, Ch A2, Ch B, Ch B2, EkA, EkB, EkB2, GcB, GcB2
A-2	(severe erosion)	ChB3,GcB3
8-15% Slope		
B	(moderate erosion)	ChC2, EkC2, GcC, GcC2
B-2	(severe erosion)	EkC3, GcC3
>15% Slope		
C		GcD, GcD2, GcD3

II. Glenelg-Manor Association

0-8% Slope		Soil Mapping Units
A.	(moderate erosion)	GeB, GcB2, MfB, MfB2
A-2	(severe erosion	GcB3, MfB3
8-15% Slope		
B	(moderate erosion)	GcC, GcC2, MfC, MfC2
B-2	(severe erosion)	GcC3, MfC3
>15% Slope		
C		MfD, MfD2, MfD3, MfE, MfE2, MfE3, MfF

Conestoga Limestone Terrain - The Conestoga Limestone Terrain occurs as a relatively narrow, discontinuous unit within the Hanover-York Valley. The topography is gently to moderately sloping topography.

The principal soil association within the Conestoga limestone terrain is the Conestoga-Duffield-Bedford-Lawrence association. Of these soils, the Conestoga silt loam is the most extensive soil in the terrain. The Conestoga silt loam is a deep well-drained soil formed on shaly limestone or calcareous schist. Slopes range from nearly level to moderately steep but the gentler slopes predominate. The subsoil has a well developed B zone of silty clay which forms a restriction to the downward movement of water. The tight, fine-grained subsoil is a primary deterent to the use of this terrainal unit for wastewater application. Soil thickness over the limestone is variable ranging from 8 to more than 40 feet and averaging about 20 feet. Wide variation in depth of weathering is typical of carbonate (limestone and dolomite) terrains.

At Hanover, the Conestoga Terrain is a broad gently sloping low-lying area of relatively slight relief. Groundwater is encountered at relatively shallow depth (generally less than 15 feet below land surface) and groundwater gradients are generally low. At other locations within the Hanover-York Valley, such as near Bair, the Conestoga limestone is situated at an intermediate topographic level between the floodplain and the uplands. There the depth to groundwater is greater, groundwater gradients are larger and groundwater movement is likely to be directed to discharge points in the bottomlands.

Specific capacities of water wells in Conestoga bedrock ranging from 0.05 to more than 13 gpm per ft. drawdown (Table 2). At Hanover, available specific capacity data on three wells indicate specific capacities consistently less than 1.0 gpm per ft. drawdown and well yields of less than 100 gpm.

Triassic Sandstone-Shale Terrain - Only a small portion of the northern part of the Codorus Creek Basin lies within the Triassic Sandstone-Shale Terrain (Figure 2). The geologic units contained in this area belong to the New Oxford Formation. The topography is nearly level to gently sloping and is a part of the area known locally as the Dover Plains.

Soils in area belong to the Penn-Lansdale-Readington association. They are generally shallow to moderately deep with interbedded sandstone and shale bedrock at generally less than 3 feet. Individual beds of

shale or sandstone range from less than 10 feet to more than 50 feet in thickness and thinner units are predominant. The rocks dip to the northwest and textural changes from sandstone to shale bedrock within short leateral distances are common.

Mixed Bedrock Terrain - The remainder of the basin consists of a complex of limestone, dolomite, shale, slate, phyllite and quartzite of Cambrian age. Extensive folding and faulting of these units has produced an area of great lithologic variety. Uniformity of bedrock conditions over any area of signficant extent is unlikely. Information to establish nature and extent of individual textural elements within this area is not available and comprehensive and detailed geologic surveys and analysis would be required to establish the textural and structural relationships.

The Mixed Bedrock Terrain contains a variety of soils related primarily to the Cardiff-Whiteford, Hagerstown, Duffield and Glenelg-Manor associations. These soils have a wide range of textural, profile and slope conditions which vary within relatively short lateral distances.

The water-yielding characteristics of the bedrock also vary widely owing to the complex distribution of lithologies. The predominant lithologies within the terrain are limestone and dolomite which characteristically display broad ranges in soil texture, soil thickness and permeability conditions.

Slope conditions also vary widely within the terrain ranging from areas of nearly level or gently sloping topography to excessively steep slopes. On the more soluble bedrock units, a karst topography containing many sinkholes has developed.

Relative Suitability of Terrainal Units for Wastewater Application

Terrainal Units Most Suited for Land Application - The Schist Terrain and the Phyllite Terrain present the best opportunities for wastewater application from the standpoint of requisite physical characteristics. These two terrains constitute the bulk of the area of the basin southeast of the Hanover-York Valley physiographic unit.

Soil profile characteristics of the Chester-Elioak-Glenelg and the Glenelg-Manor associations within the Schist Terrain as displayed by the site area investigations at Glen Rock indicate less intense development of the B-zone in terms of clay content and thickness than in the other terrainal units within the basin. Average permeability levels of

about 0.5 feet per day are, however indicative of the need for the careful adjustment of application procedures to prevent ponding.

The principal advantage of the Schist Terrain is in the somewhat higher potential transmissivity of the weathered and unweathered schist especially in the area of the Wissahickon formation. Specific capacity data from wells in this unit indicates that somewhat better opportunities for drainage control by use of wells and interceptor ditches and tiles are likely to exist in this unit as compared to other terrainal areas within the basin.

The Phyllite Terrain including the Harpers Phyllite and Chickies Slate geologic units is somewhat less favorable than the Schist Terrain from the standpoint of soil permeability and drainage control requirements but is somewhat more favorable from the standpoint of topography. Investigations in the Phyllite terrain southeast of Spring Grove indicated thicker development of the B-horizon of the soil profile with slightly lower permeability values. In addition, wells in the phyllite have a lower average specific capacity than do water wells in the Schist Terrain.

Terrainal Units Least Suited for Land Application - The terrainal areas least suited for land application of wastewater in the Codorus Creek Basin are the Conestoga Limestone Terrain, the Mixed Bedrock Terrain and the Triassic Sandstone-Shale Terrain.

The principal limitations of the Conestoga Limestone Terrain is the tight subsoil produced by weathering process and the generally high water table conditions at Hanover. In addition, the presence of solution channels in the underlying bedrock and the variable depth to bedrock indicate that groundwater quality control is likely to be difficult.

In the Mixed Bedrock Terrain, the rapid and unpredictable changes in lithologic character of the bedrock make identification and analysis of land tracts of any significant extent unreliable. The most suitable areas topographically for land application are those parts of the terrain underlain by limestone and dolomite bedrock. These regions have restrictions similar to those in the Conestoga limestone terrain.

The Triassic Sandstone-Shale Terrain is limited in its utility for wastewater application because of the shallow depth to unweathered bedrock (generally less than 3 feet) and due to the stratified nature of the relatively thin beds of sandstone and shale. The stratified nature of the lithologic units results in pronounced changes in texture within short lateral distances and marked changes in texture with depth which interrupt and otherwise disturb subsurface flow patterns.

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FIGURE 1

GEOLOGY OF THE
CODORUS CREEK DRAINAGE BASIN

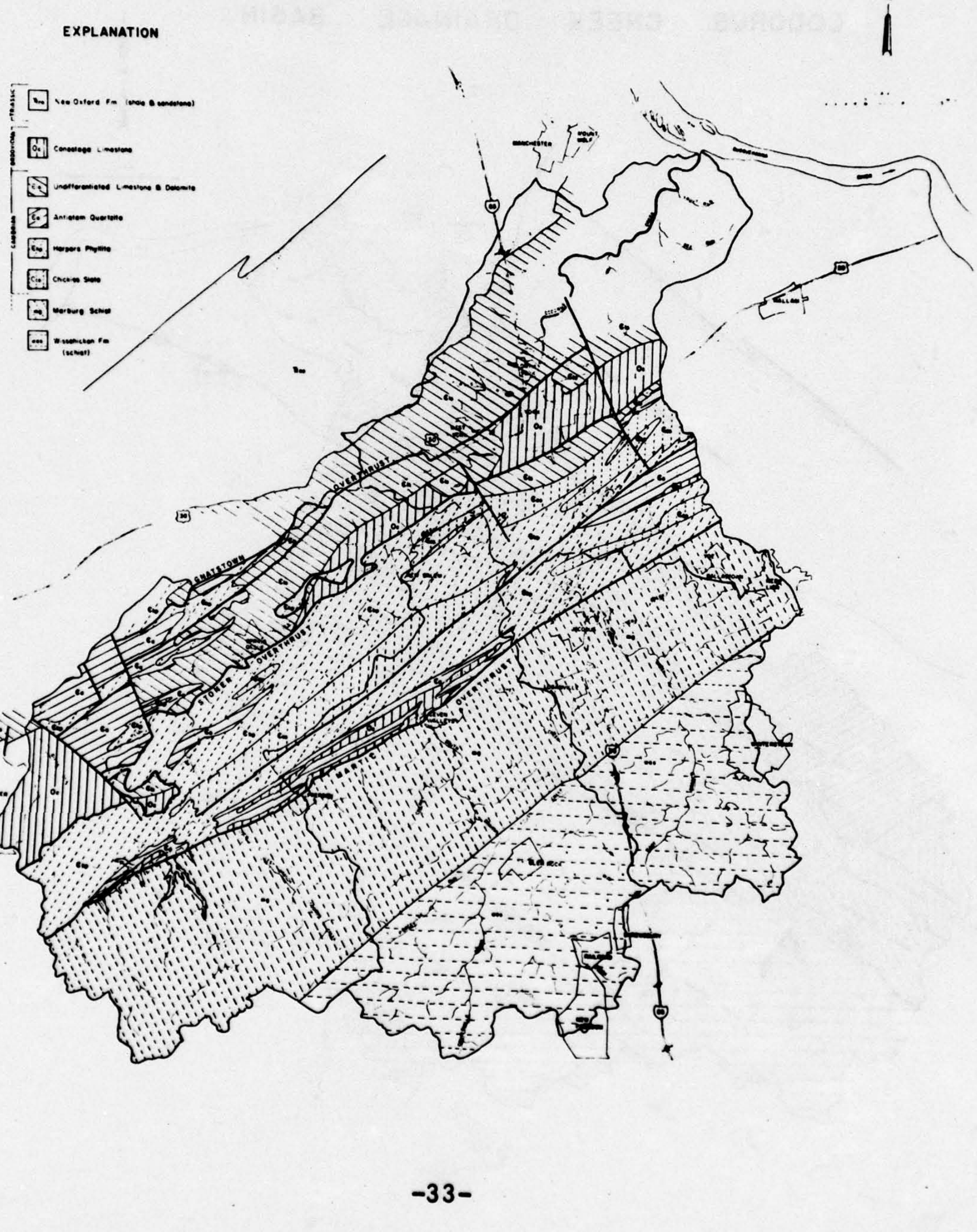


FIGURE 2

TERRAINAL UNITS
RELATIVE TO WASTE WATER APPLICATION,
CODORUS CREEK DRAINAGE BASIN

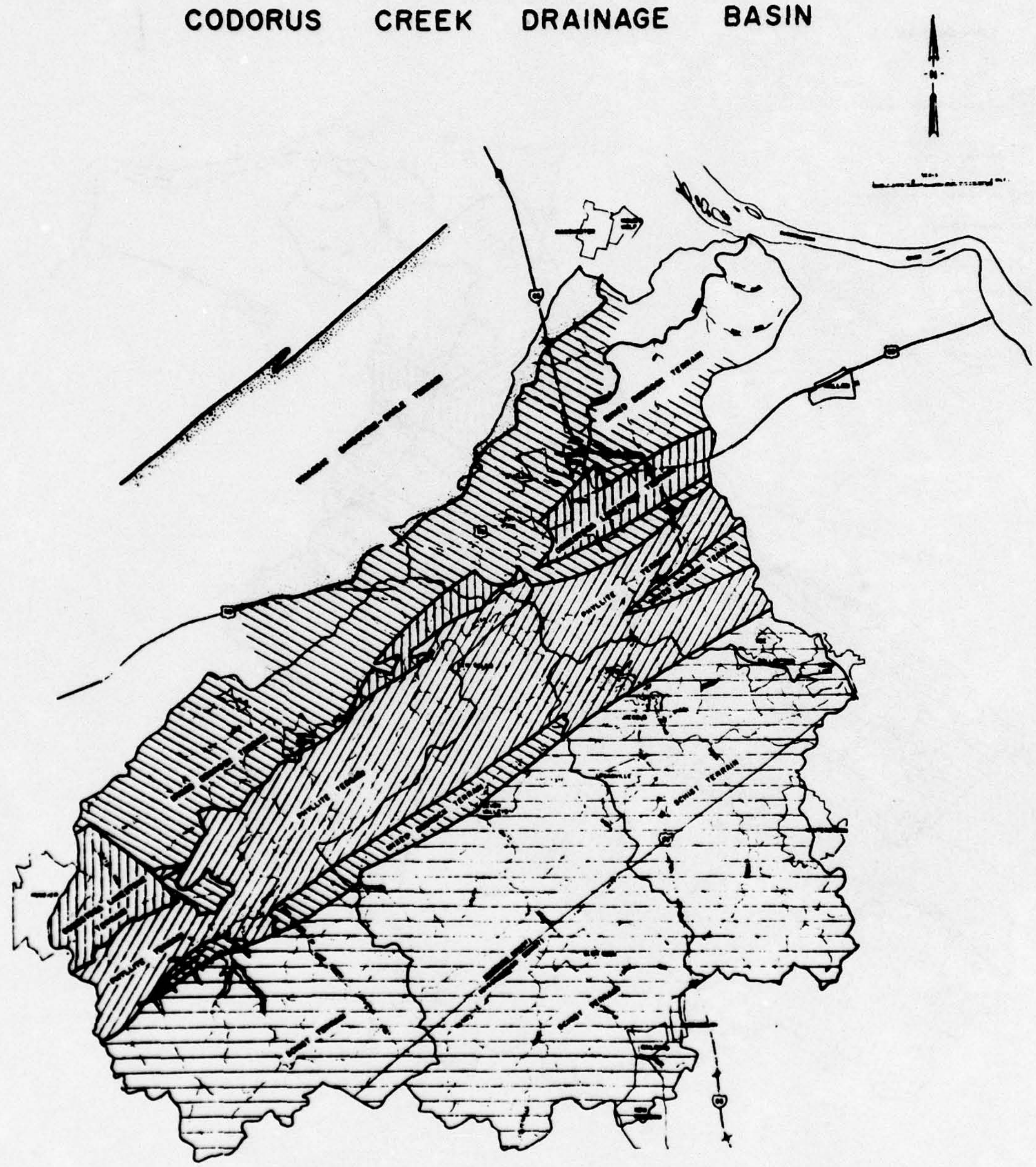
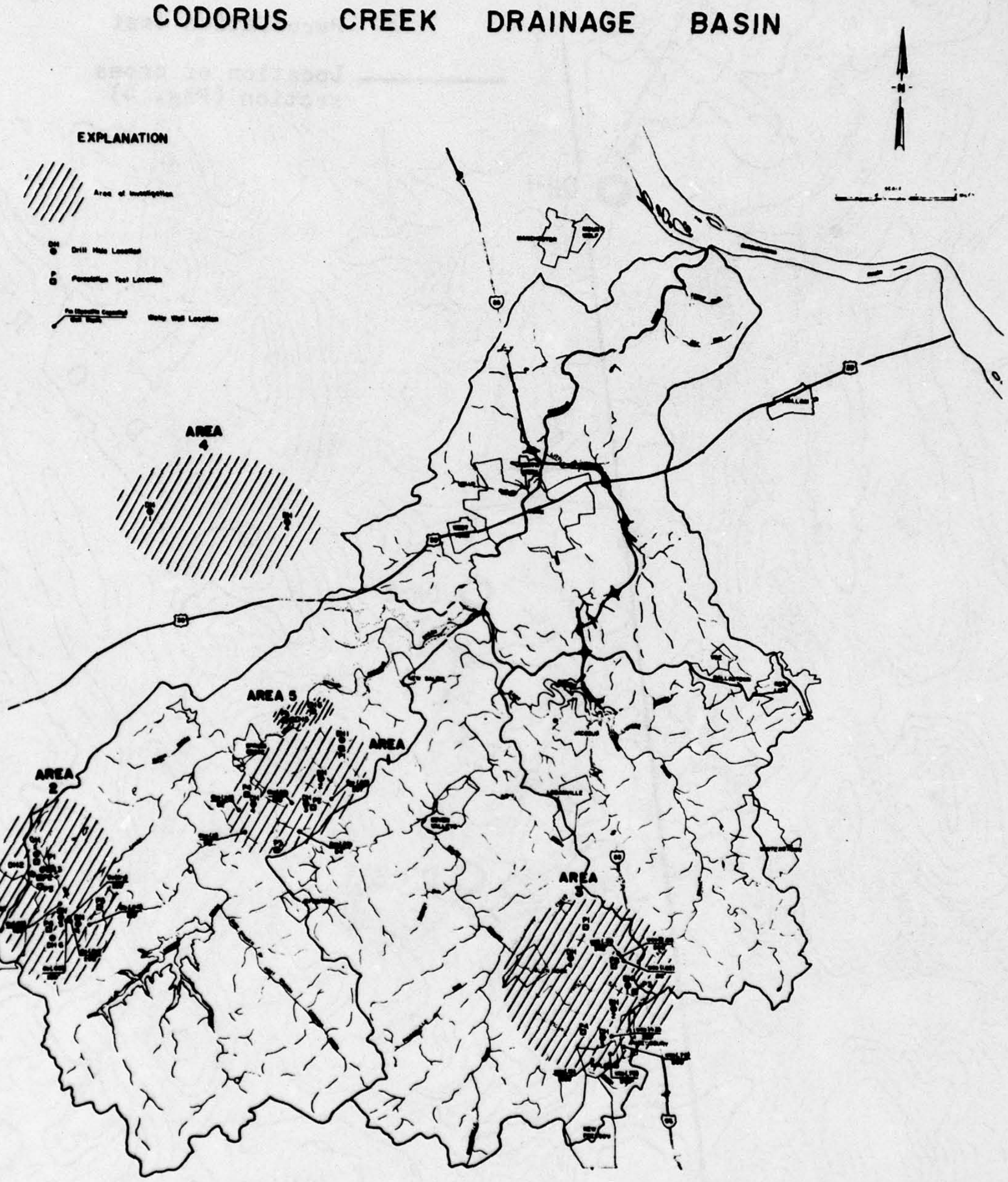


FIGURE 3

AREAS OF GEOLOGIC INVESTIGATION

CODORUS CREEK DRAINAGE BASIN



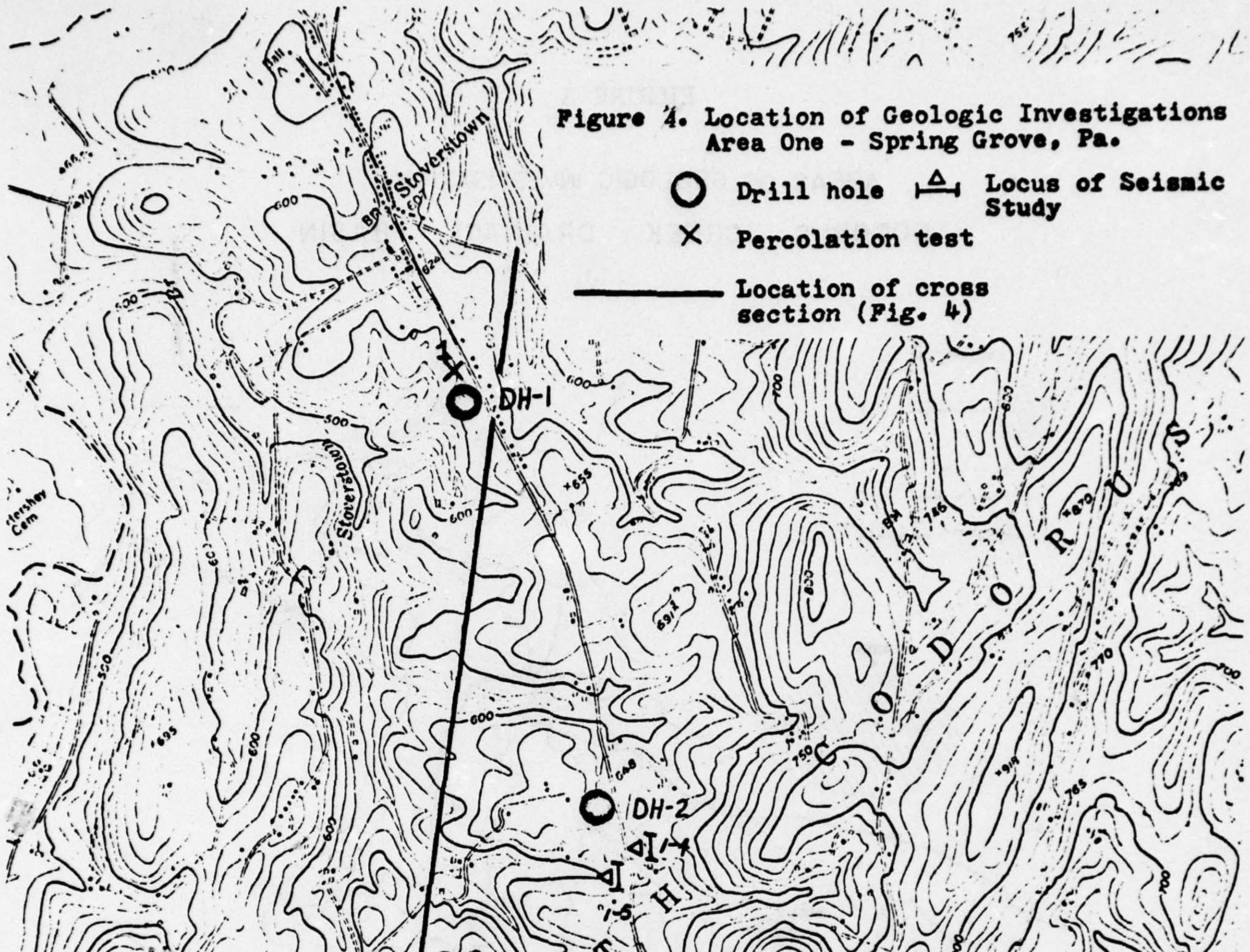


Figure 4. Location of Geologic Investigations Area One - Spring Grove, Pa.

FIG. 4

CROSS SECTION – AREA ONE – SPRING GROVE

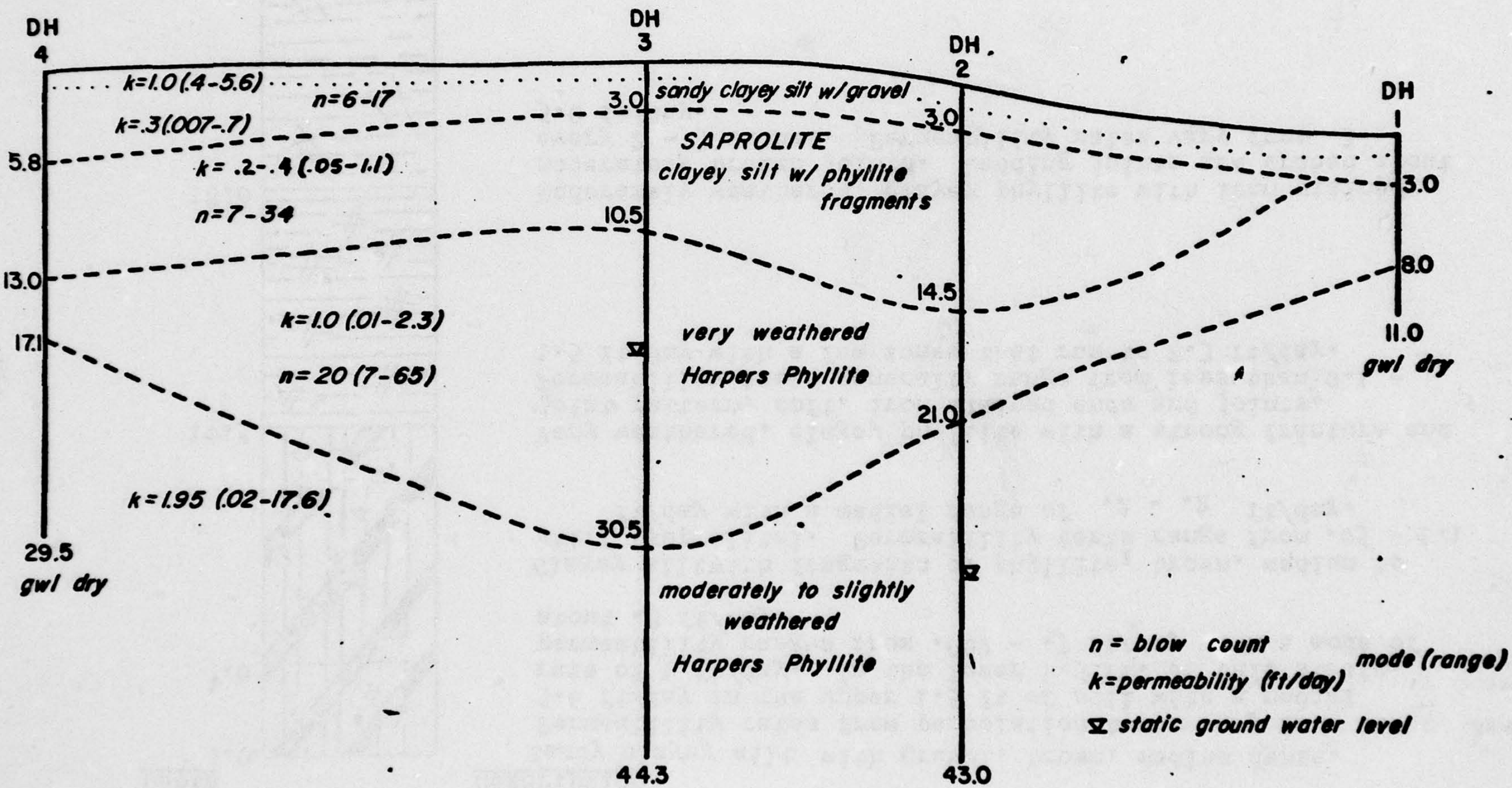
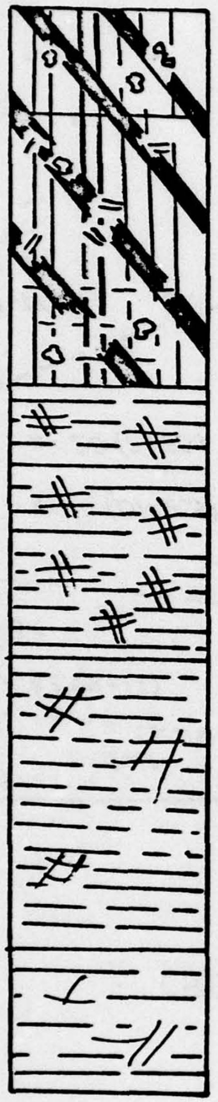


Figure 6. Typical Drilling Log from the Harpers Phyllite (Area 1) Spring Grove,Pa.



Depth	Description
0.0	Sandy clayey silt with gravel, brown, medium dense. Permeability rates from percolation tests vary from 0.4 5.6 ft/day in the upper 1.5 ft of soil with a medial rate of 1 ft/day. In the lower 1.5 ft. of this strata, permeability ranges from .007 - .7 ft/day with a mode of about .3 ft/day.
3.0	Clayey siltwith fragments of phyllite, brown, medium to stiff (saprolite). Permeability tests range from .05 - 1.1 ft/day with a medial range of .2 - .2 ft/day.
10.5	Very weathered, clayey phyllite with a strong fracture and joint pattern, soft, iron stained ends and joints. Permeability tests generally range from less than 0.1 - 1.5 ft/day with a few zones that run to 2.3 ft/day.
18.0	Moderately weathered, clayey phyllite with iron stained, moderately broken joints. Bedding joints are spaced about every 2 - 3 inches. Permeability rates vary from .1 - 5.0 ft/day.
26.0	Slightly weathered phyllite, with some jointing. Few of the joints are open with iron staining. Permeability rates are dependent on the density and openness of the joints and range from 1 - 20 ft/day.

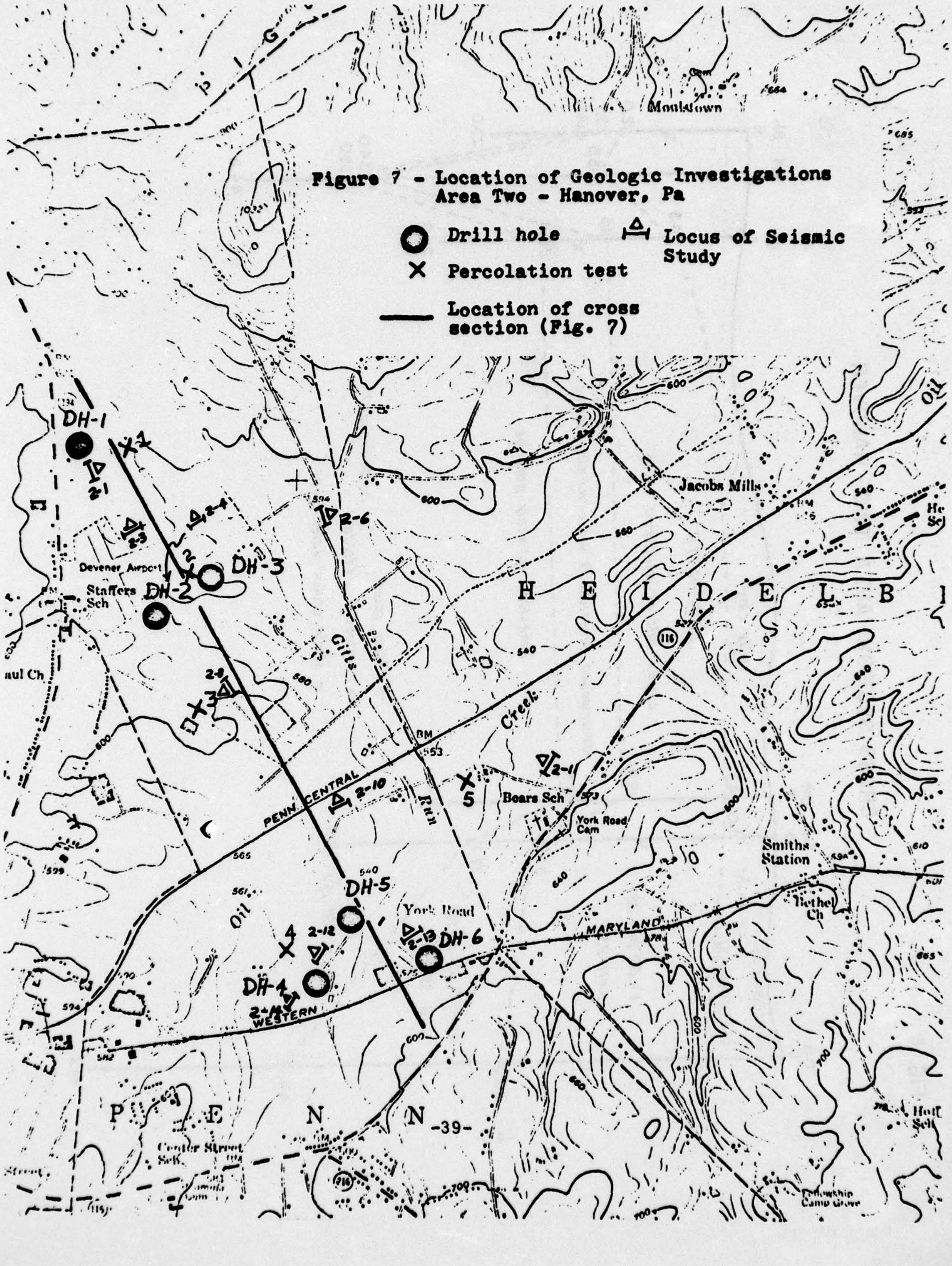


Figure 7 - Location of Geologic Investigations
Area Two - Hanover, Pa
Drill hole
Locus of Seismic Study
Percolation test
Location of cross section (Fig. 7)
DH-1
DH-2
DH-3
DH-4
DH-5
DH-6
Devener Airport
Staffers Sch
Jacobs Mills
H E I D E L B
PENN CENTRAL
Creek
Run
Gills
Bears Sch
York Road Cem
York Road
Smiths Station
Bethel Ch
MARYLAND
WESTERN
Oil
P E N N
Center Street Sch
Moulstown

FIG. 8

CROSS SECTION - AREA TWO - HANOVER

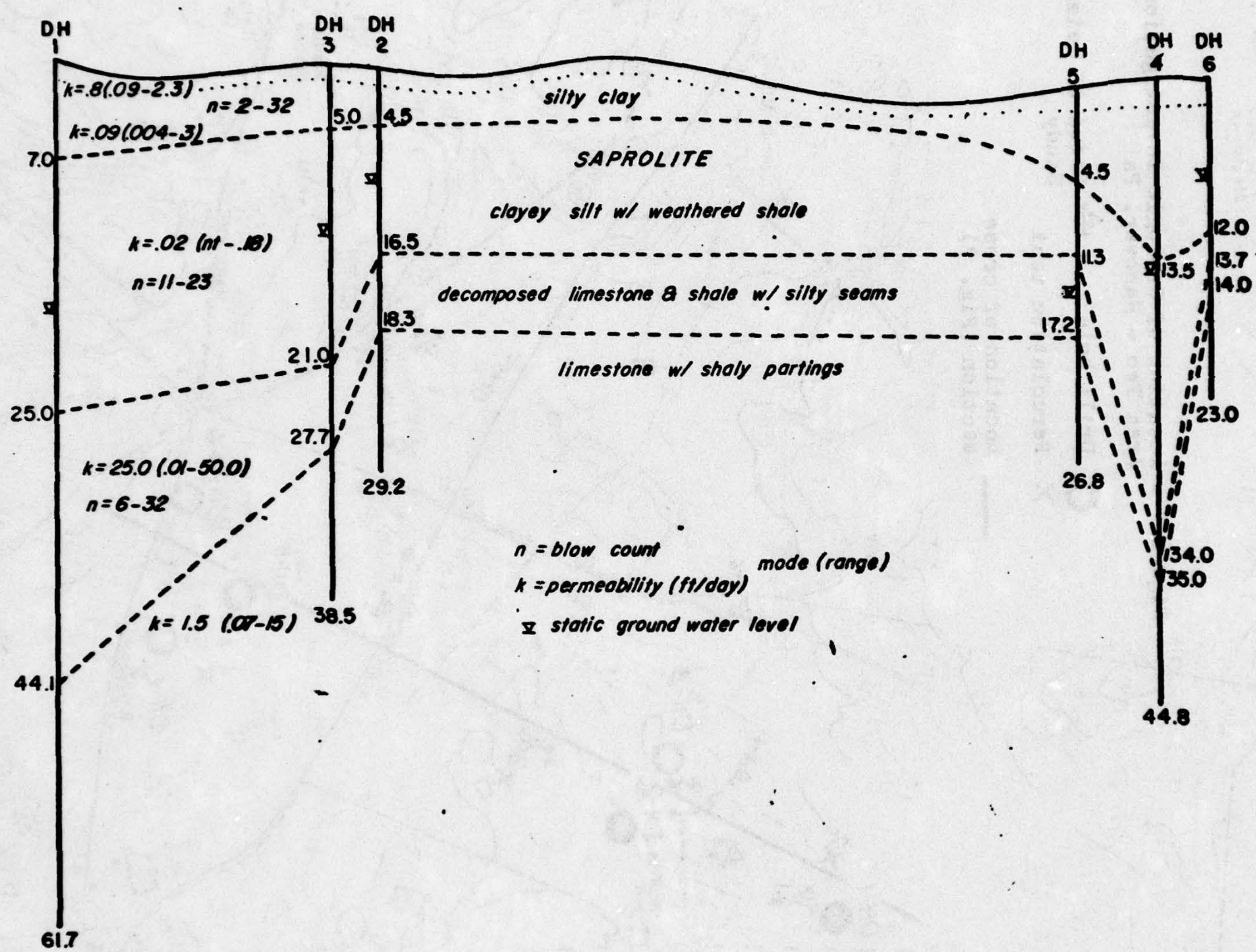
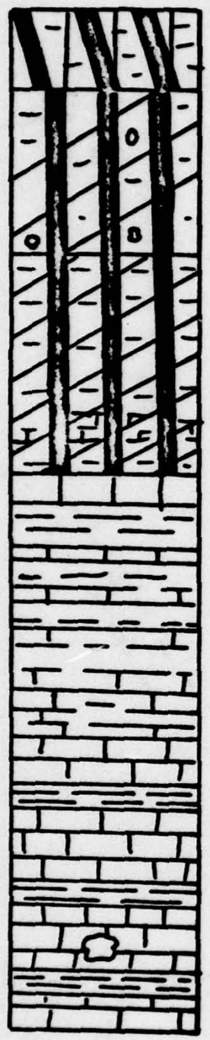


Figure 9. Typical Drilling log from the Conestoga Limestone Area (2), Hanover, Pa.



Depth	Description
0.0 – 1.5	Silty clay, brown, few shale fragments, medium dense. Permeability rates range from .09 - 2.3 ft/day with a mode of about 0.8 ft/day.
1.5 – 5.0	Clayey silt, brown, medium density, with shale fragments and a few quartz gravels. Permeability rates vary from .004 - .3 ft/day with a mode of about .09 ft/day.
5.0 – 15.0	Clayey silt with shale fragments, brown, soft. The soil structure reflects the structure of the weathered rock (saprolite). There are a few zones of limestone fragments in a clayey silt matrix. Permeability tests in this horizon vary from .01 - .18 ft/day with a mode of about .02 ft/day.
15.0 – 23.0	Very weathered, dark-gray, limy shale with clay seams and silty limestone, very soft and broken. This zone appears to be derived from shaly limestone that has been leached. There is a zone of silty limestone that is very weathered and decomposed at the base. Permeability rates are usually .05 - .8 ft/day but zones where limestone was formerly present and calcite seams and joints may have rates up to 50 ft/day.
23.0 – 45.0	Gray limestone with interbedded, dark-gray, slaty shale. Calcite seams form in rectangular- patterned joints. Generally the permeability rate varies from 1 - 5 ft/day but it exceeds 100 ft/day along open joints or cavities that are less then 1 foot in diameter. Where no joints are present, there is little permeability.

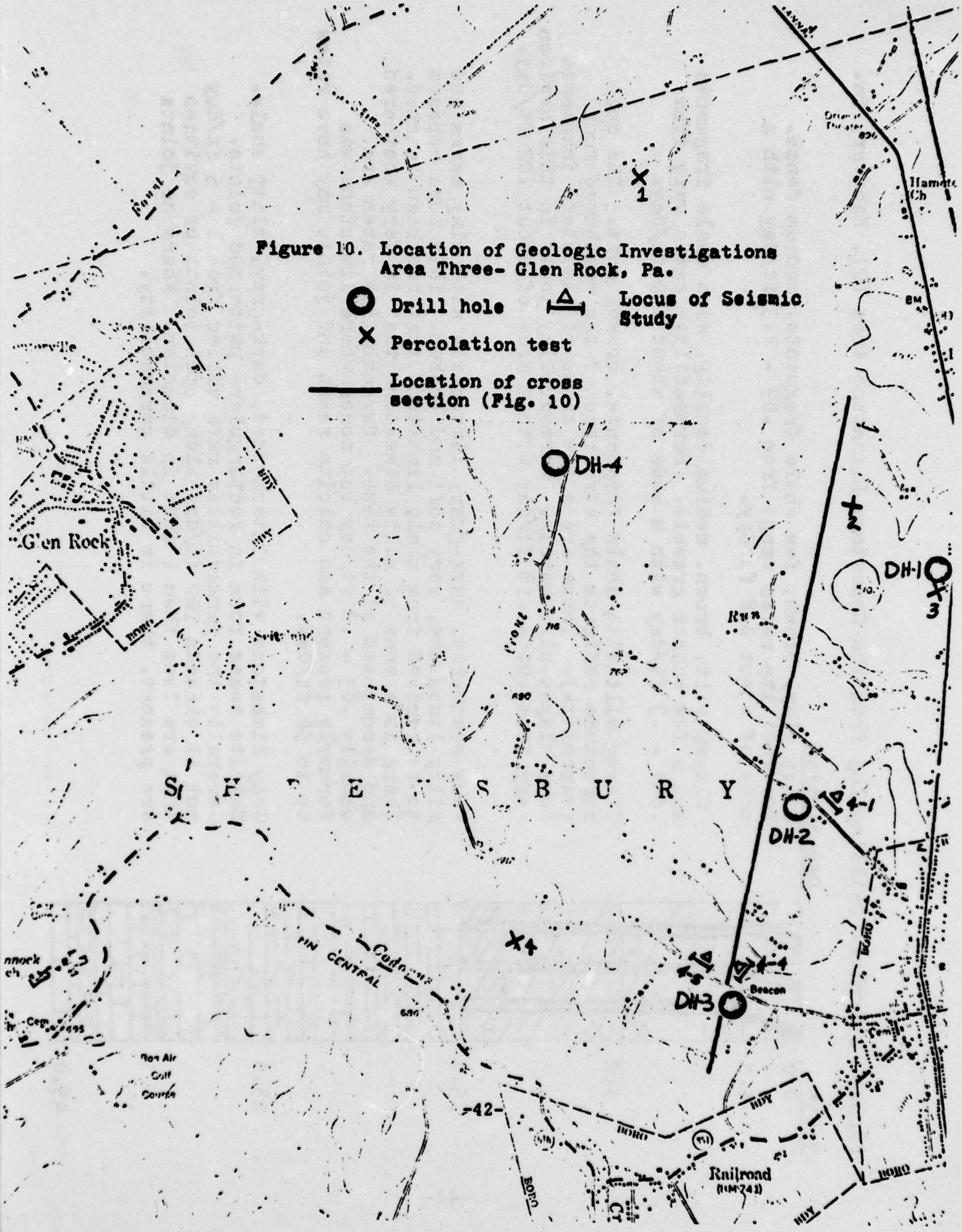


Figure 10. Location of Geologic Investigations
Area Three- Glen Rock, Pa.
Drill hole
Locus of Seismic Study
Percolation test
Location of cross section (Fig. 10)
DH-4
DH-1
DH-2
DH-3
Glen Rock
S H R E W S B U R Y
Run
Beacon
Railroad
Bon Air Golf Course
PENN CENTRAL
Codorus
-42-

FIG. 11

CROSS SECTION - AREA THREE - GLEN ROCK

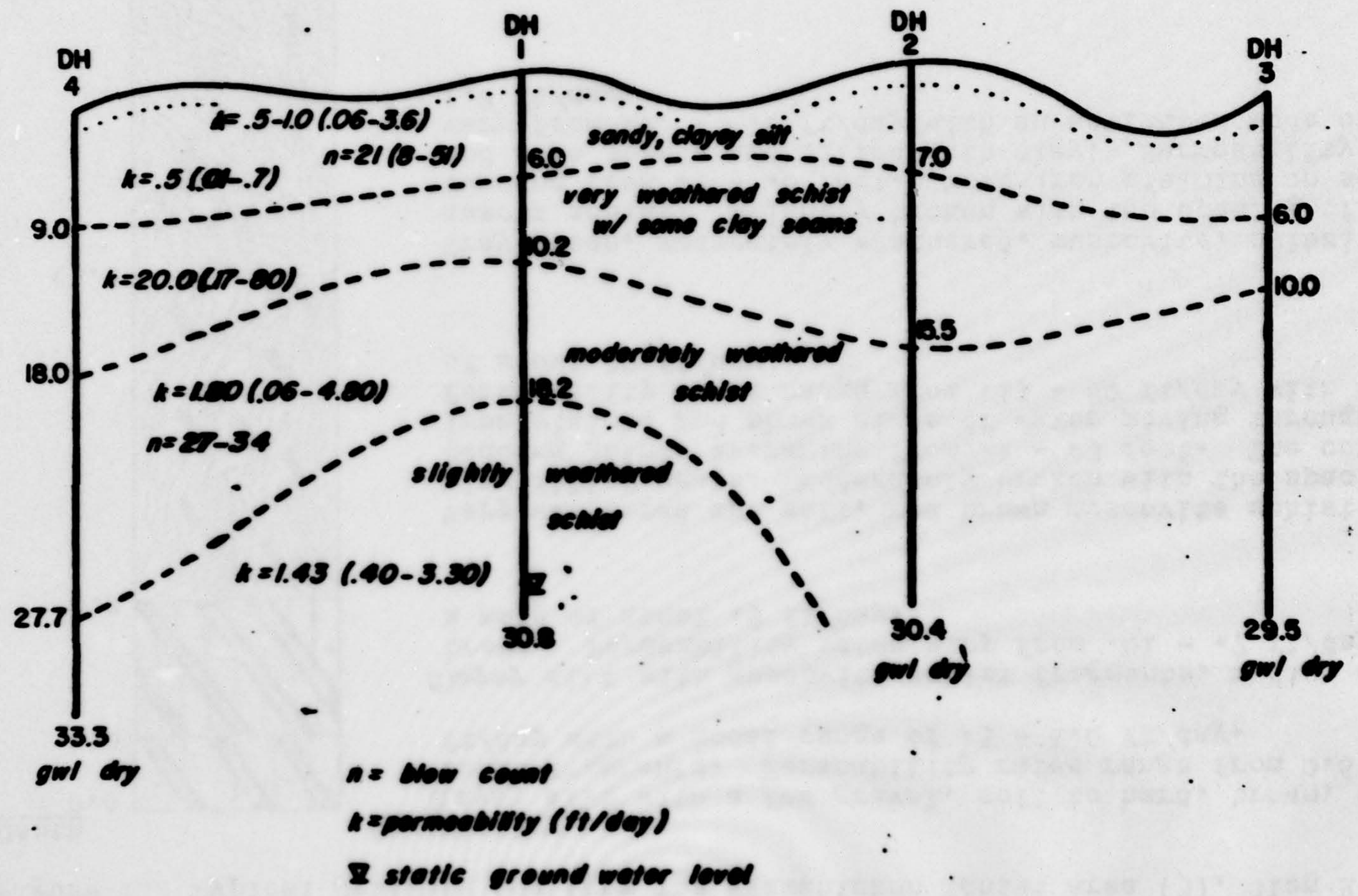
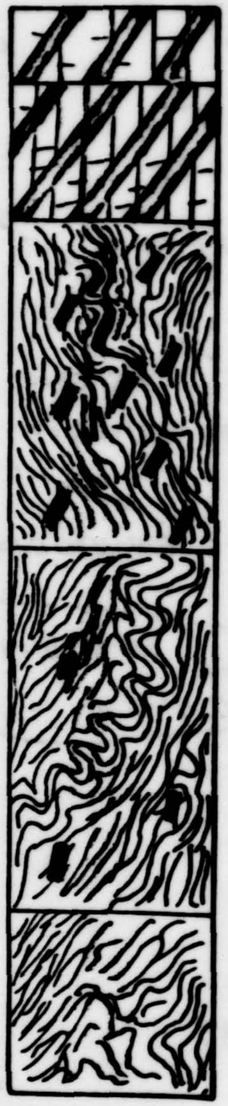


Figure 12. Typical Drilling Log from the Wissahickon Schist Area (3), Glen Rock, Pa.



Depth	Description
0.0 – 2.0	Clayey silt with a few gravel, soft to hard, brown, some shale fragments. Permeability rates range from 0.6 - 3.5 ft/day with a modal range of .5 - 1.0 ft/day.
2.0 – 6.0	Clayey silt with muscovite schist fragments, medium density, brown. Permeability rates vary from .01 - .7 ft/day with a mode of about .5 ft/day.
6.0 – 15.0	Very weathered and soft, red brown muscovite schist with clay filled seams. Moderately broken with the spacing of bedding joints averaging from .1 - .3 feet. The core is iron stained and shows signs of water moving through it. Permeability rates range from .17 - 80 ft/day with a mode of about 20 ft/day.
15.0 – 25.0	Gray-green, moderately weathered, muscovite, chlorite, quartz schist. Slightly broken with the spacing of joints running from .3 - .8 feet. Some iron staining on seams and some joints are filled with clay. Permeability rates vary from .06 - 4.8 ft/day with an estimated mode of about 1.8 ft/day.
25.0 – 30.0	Slightly weathered, gray chlorite, biotite, muscovite, quartz schist. Slightly broken with pieces of core that fit well together. Some slight iron stains on joints and seams. Permeability rates range from .4 - 3.3 ft/day and have an estimated medial rate of about 1.4 ft/day.

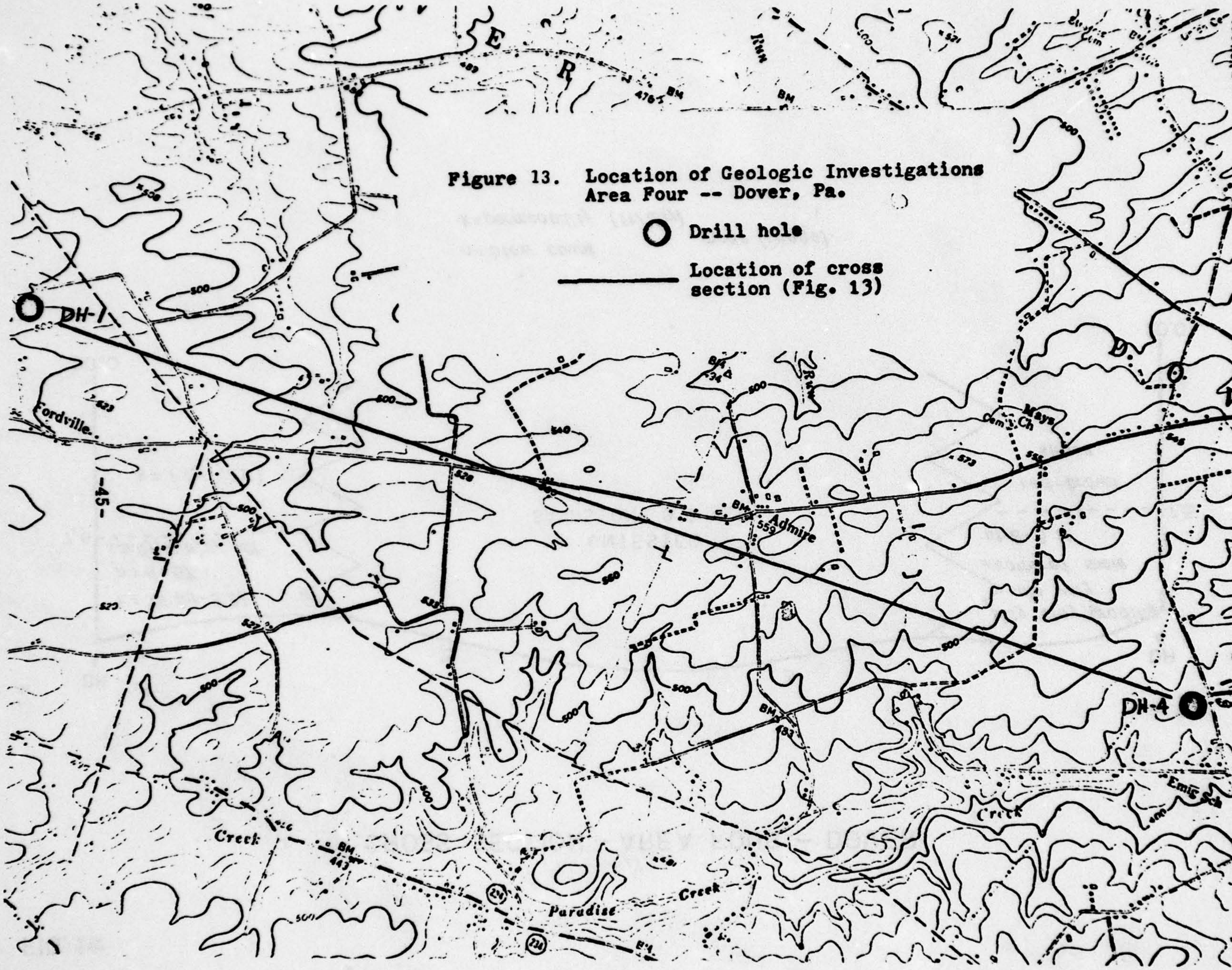


Figure 13. Location of Geologic Investigations Area Four -- Dover, Pa.

FIG. [illegible]

CROSS SECTION - AREA FOUR - DOVER

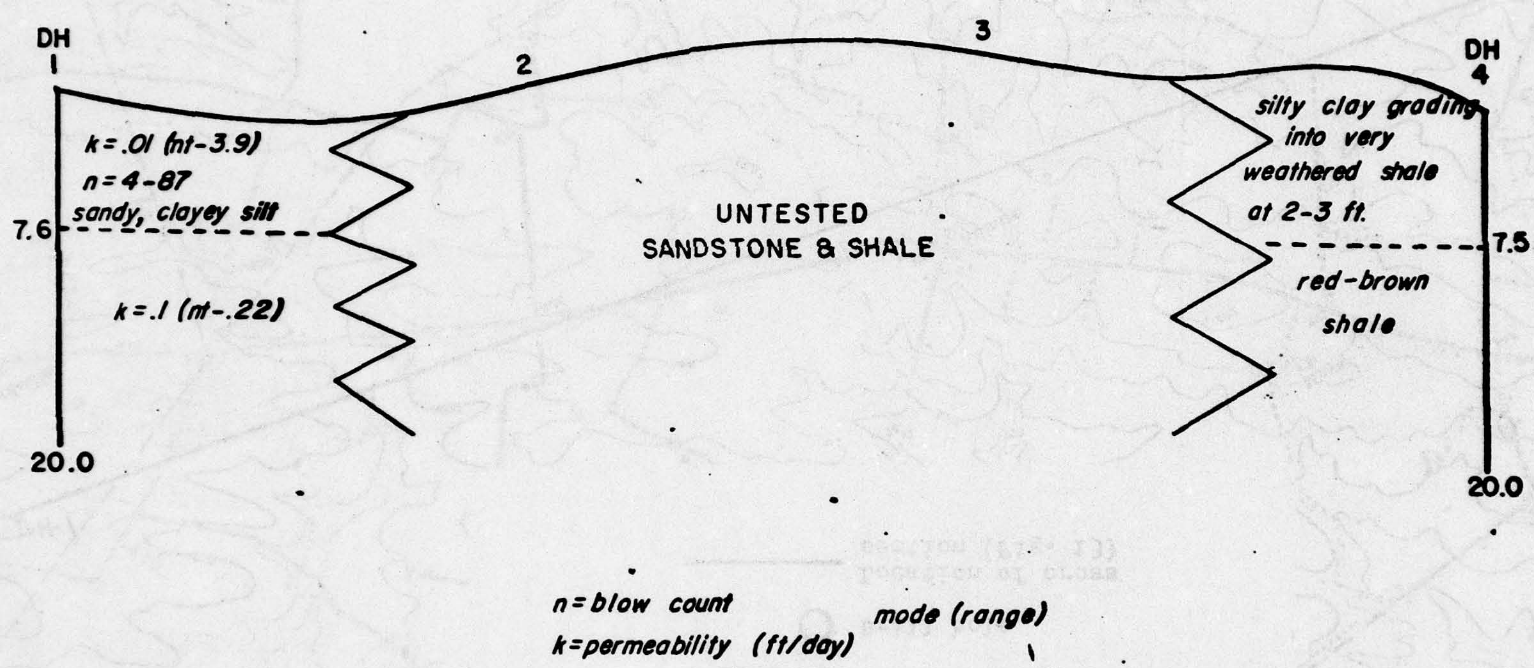
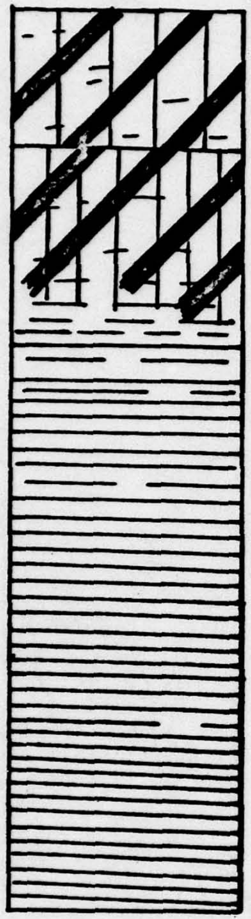


Figure 15. Typical Drilling Log from the New Oxford Shale Area (4), Dover, Pa.

Depth	Description
0.0	Silty clay with shale fragments, soft, red brown. Permeability rates are variable with the upper foot of soil having a rate of about 1 - 4 ft/day in percolation tests and lower zones varying from .002 to .01 ft/day.
3.0	Silty clay with shale fragments increasing toward the base of the strata. Stiff to very compact, red brown. The strata grades into very weathered red clay shale. Strate is a saprolite of the red shale. Permeability tests in the zone vary from 0 - 3.9 ft/day with an estimated mode of .01 ft/day.
7.5	Reddish brown shale of the New Oxford formation. Core is broken into pieces from .3 - 1.0 feet long that fit together fairly well. A few cross joints appear to be more broken. Permeability rates in this zone range from 0 - .22 ft/day at low heads and the mode is estimated to be about 0.1 ft/day.
20.0	



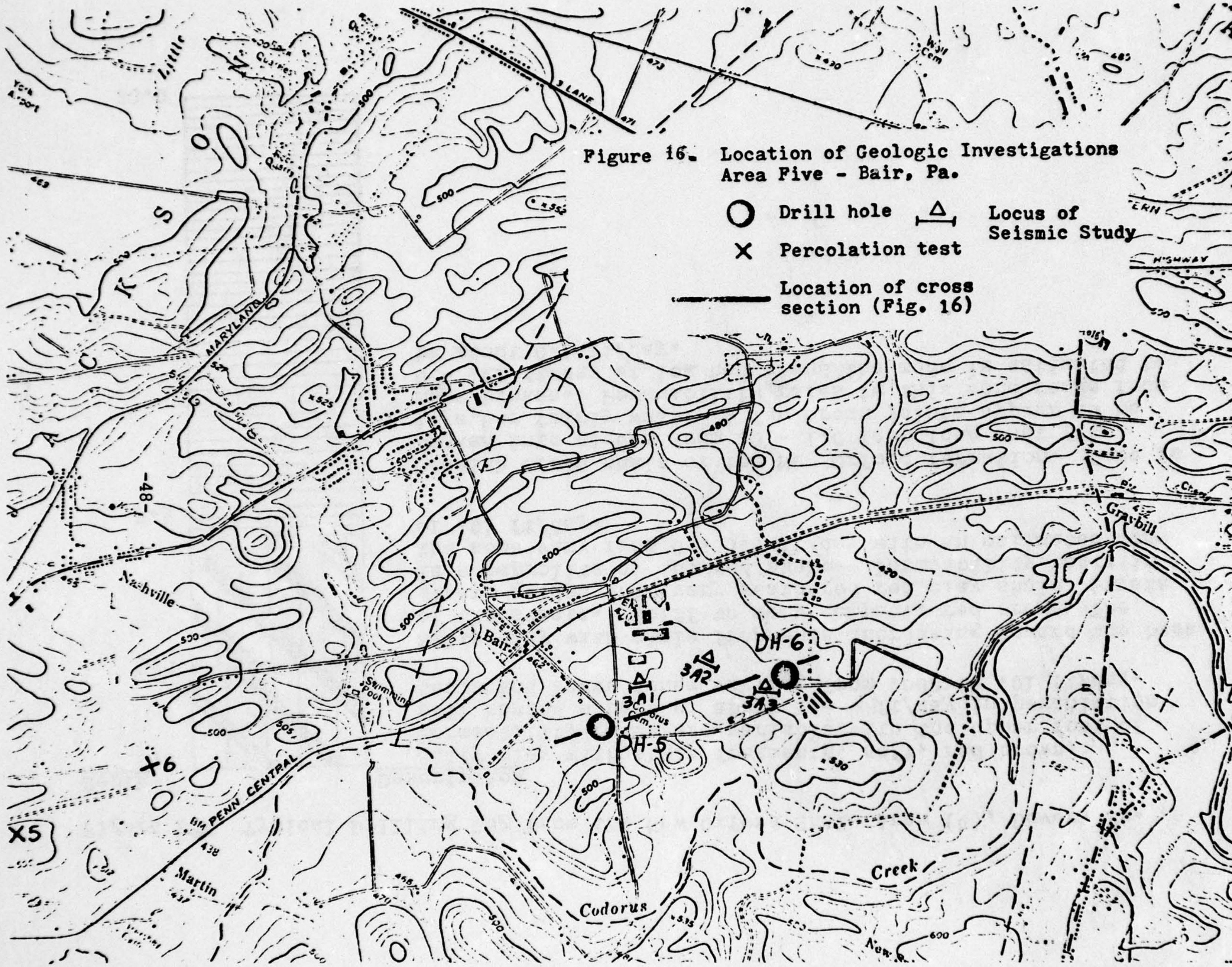
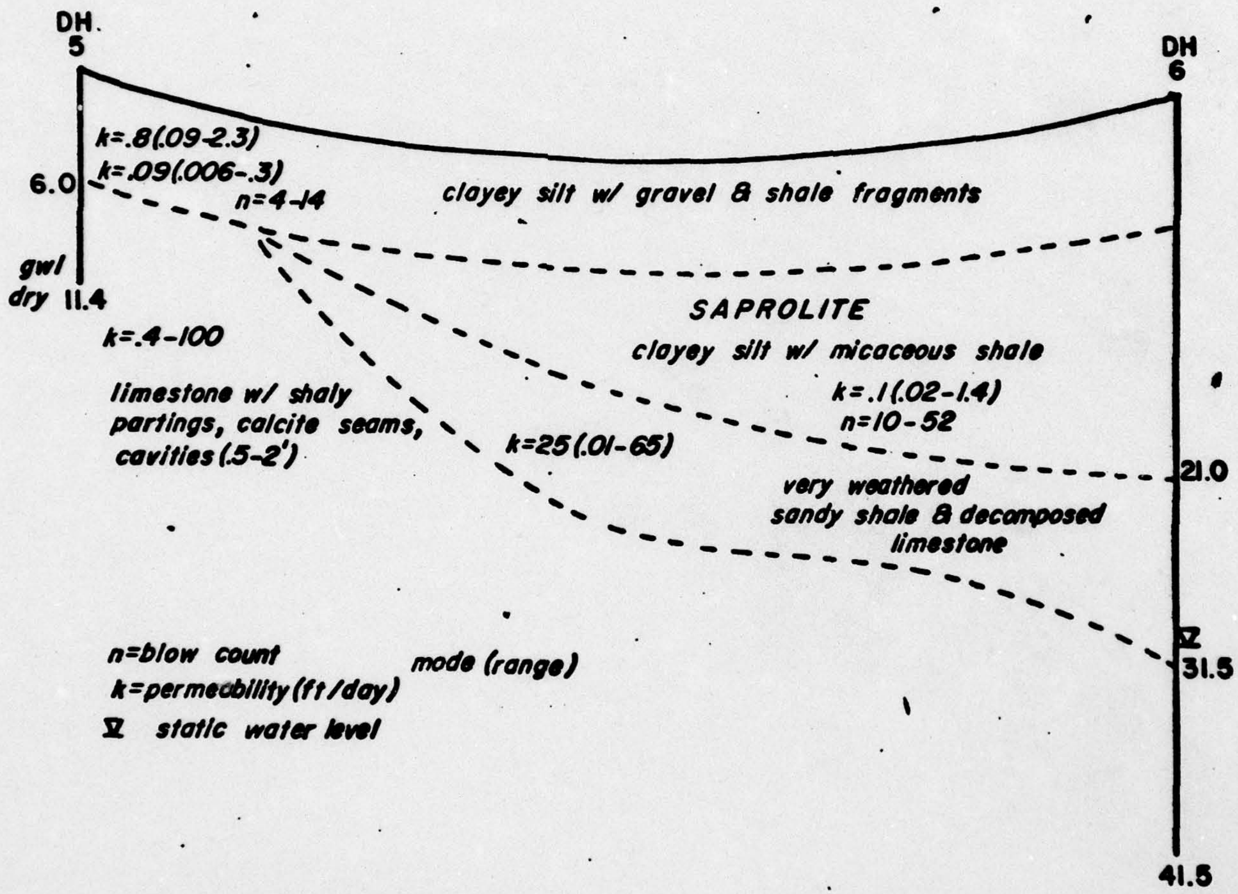


Figure 16. Location of Geologic Investigations Area Five - Bair, Pa.

FIG. 12

CROSS SECTION — AREA FIVE - BAIR



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THE CODORUS CREEK WASTEWATER MANAGEMENT STUDY. APPENDIX A. TECH--ETC(U)
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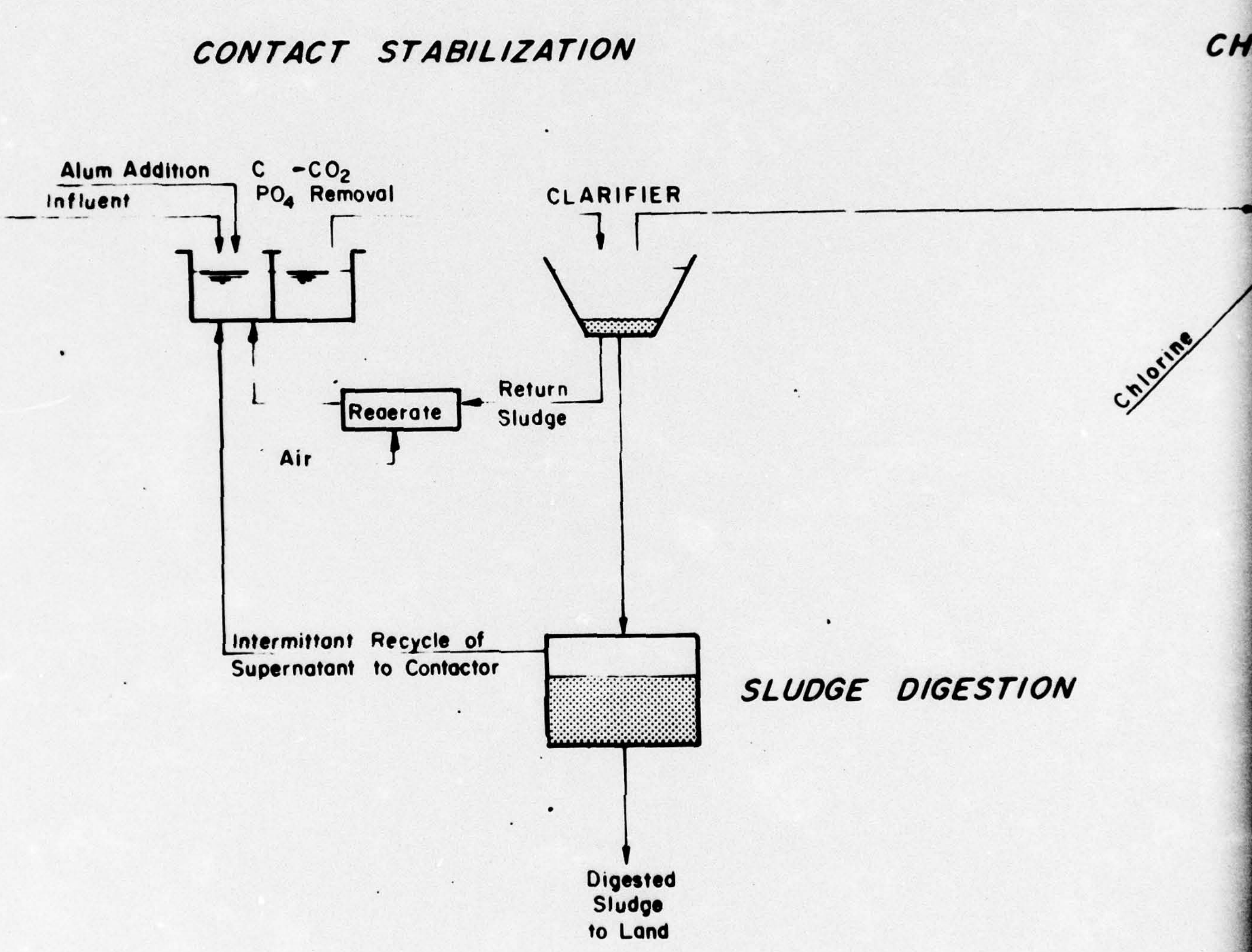
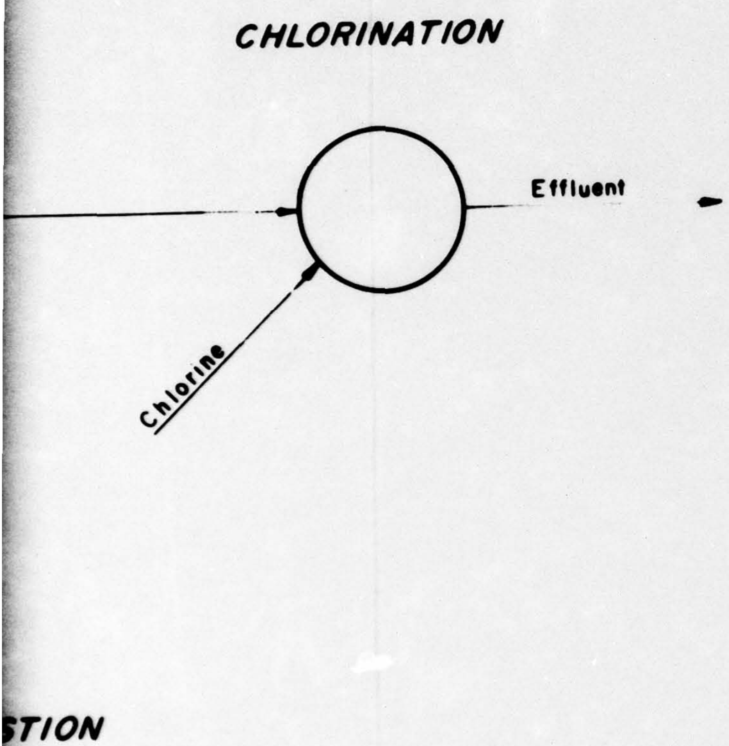
TYPE A WASTEWATER TREATMENT SYSTEM

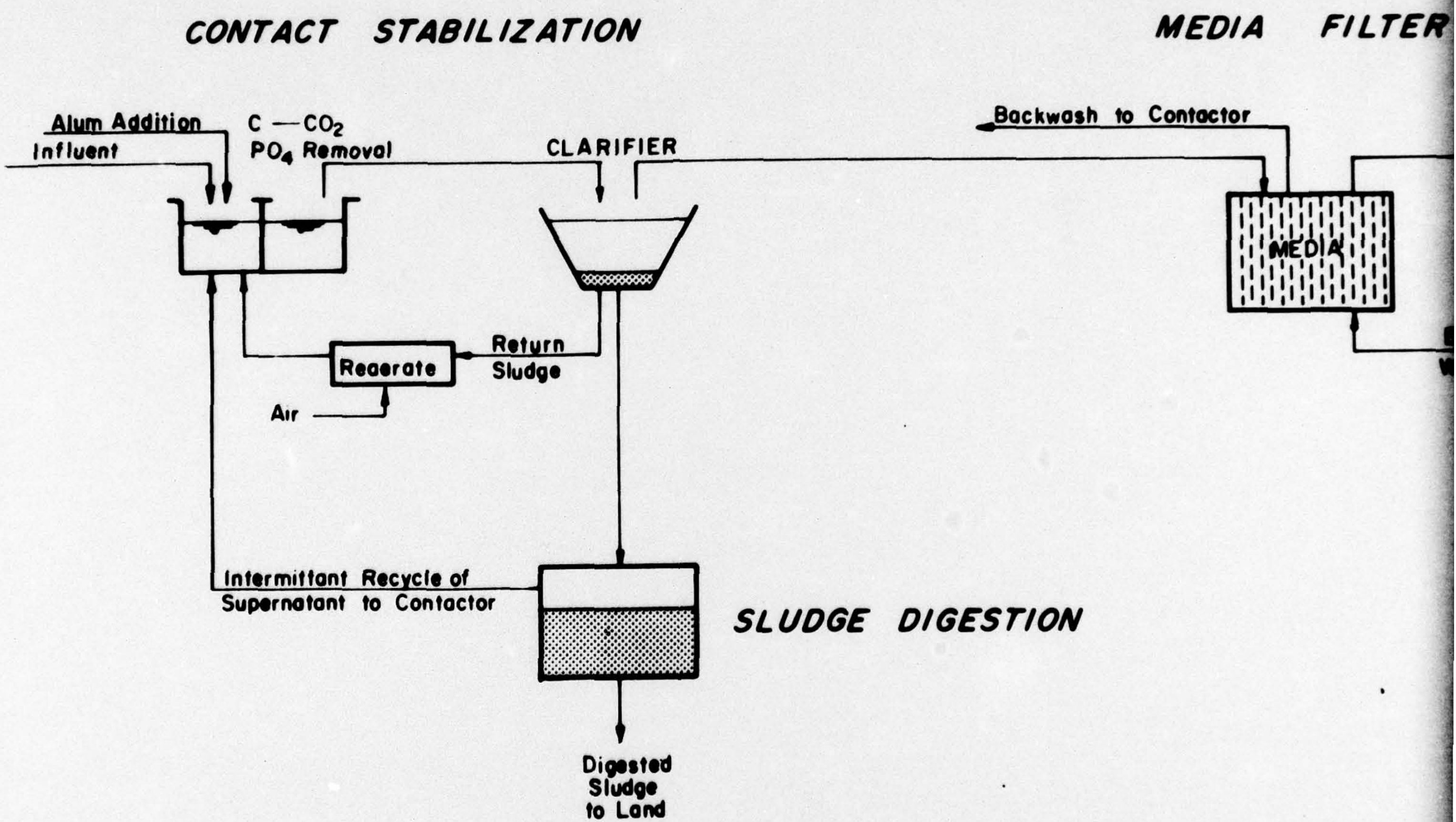


ENT SYSTEM

EXHIBIT III-4

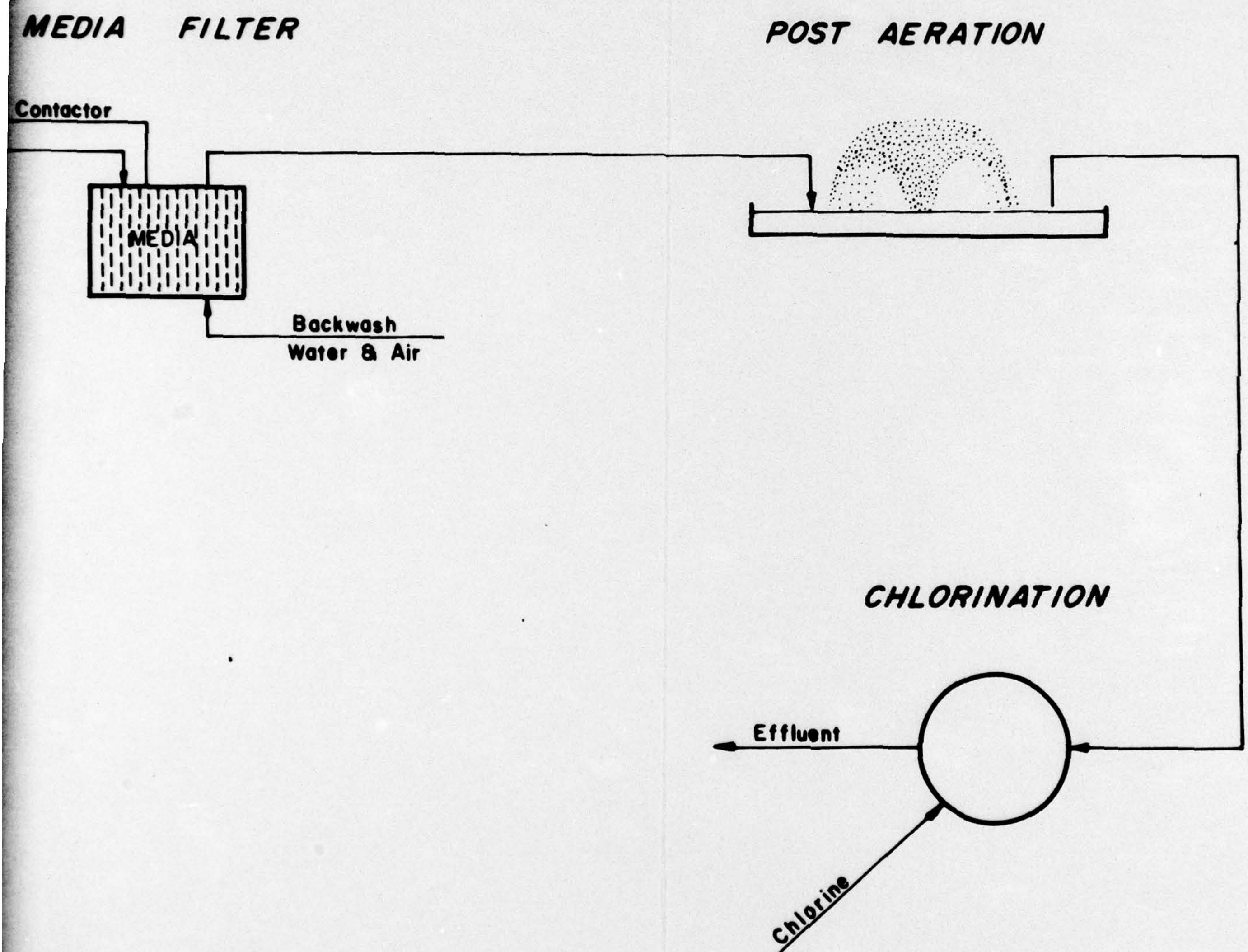


TYPE B WASTEWATER TREATME

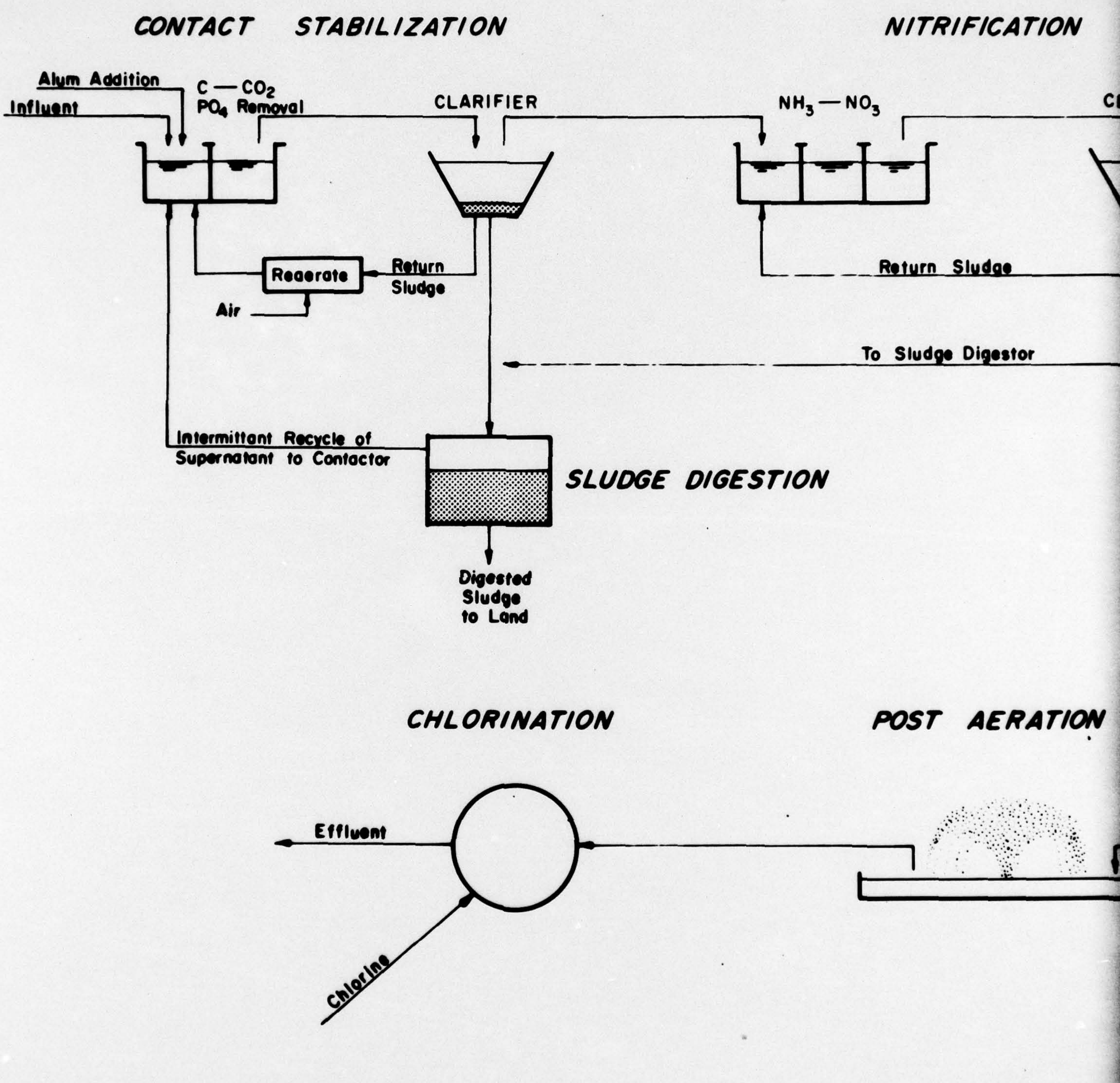


TER TREATMENT SYSTEM

EXHIBIT III-5



TYPE C WASTEWATER TREAT



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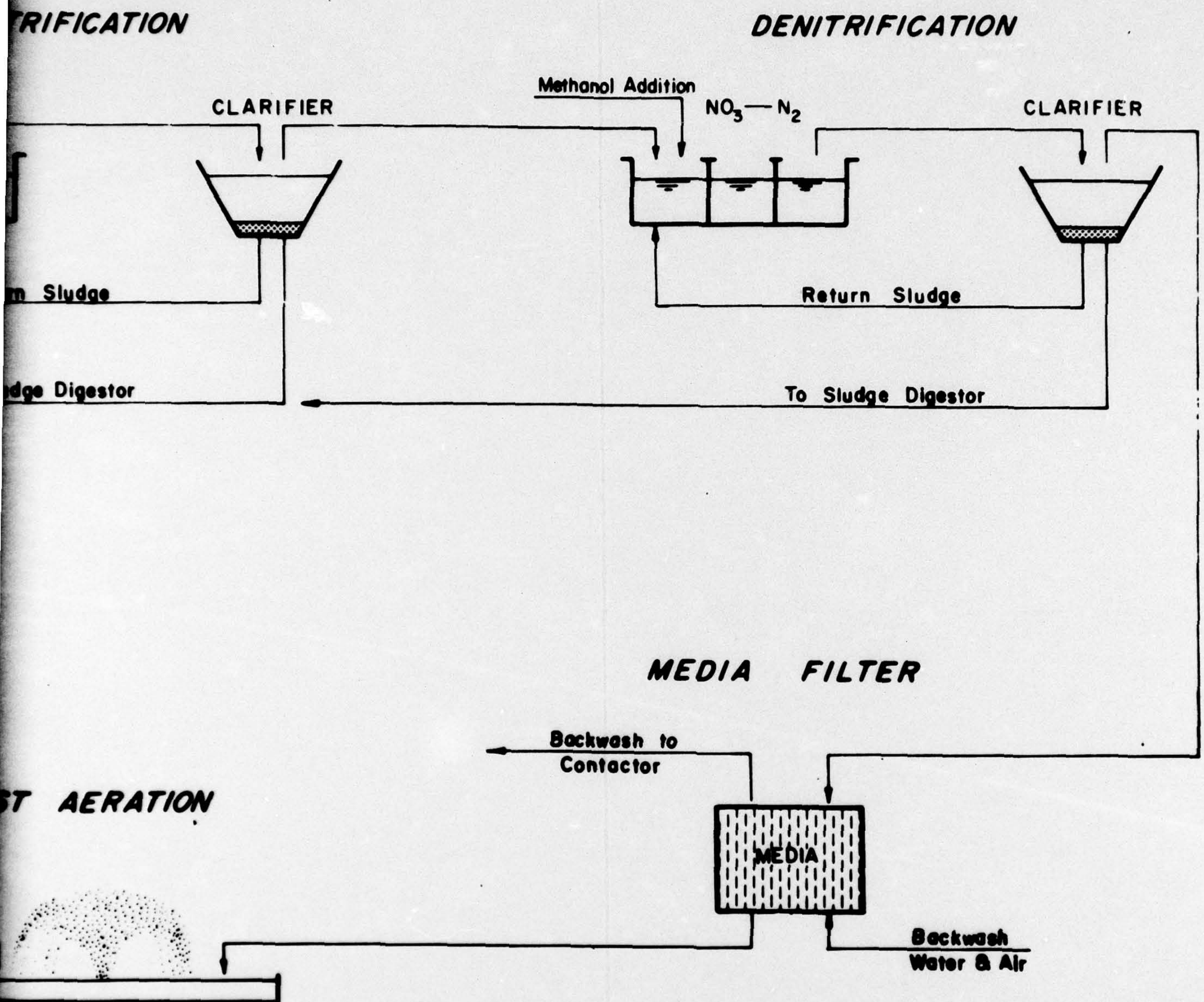
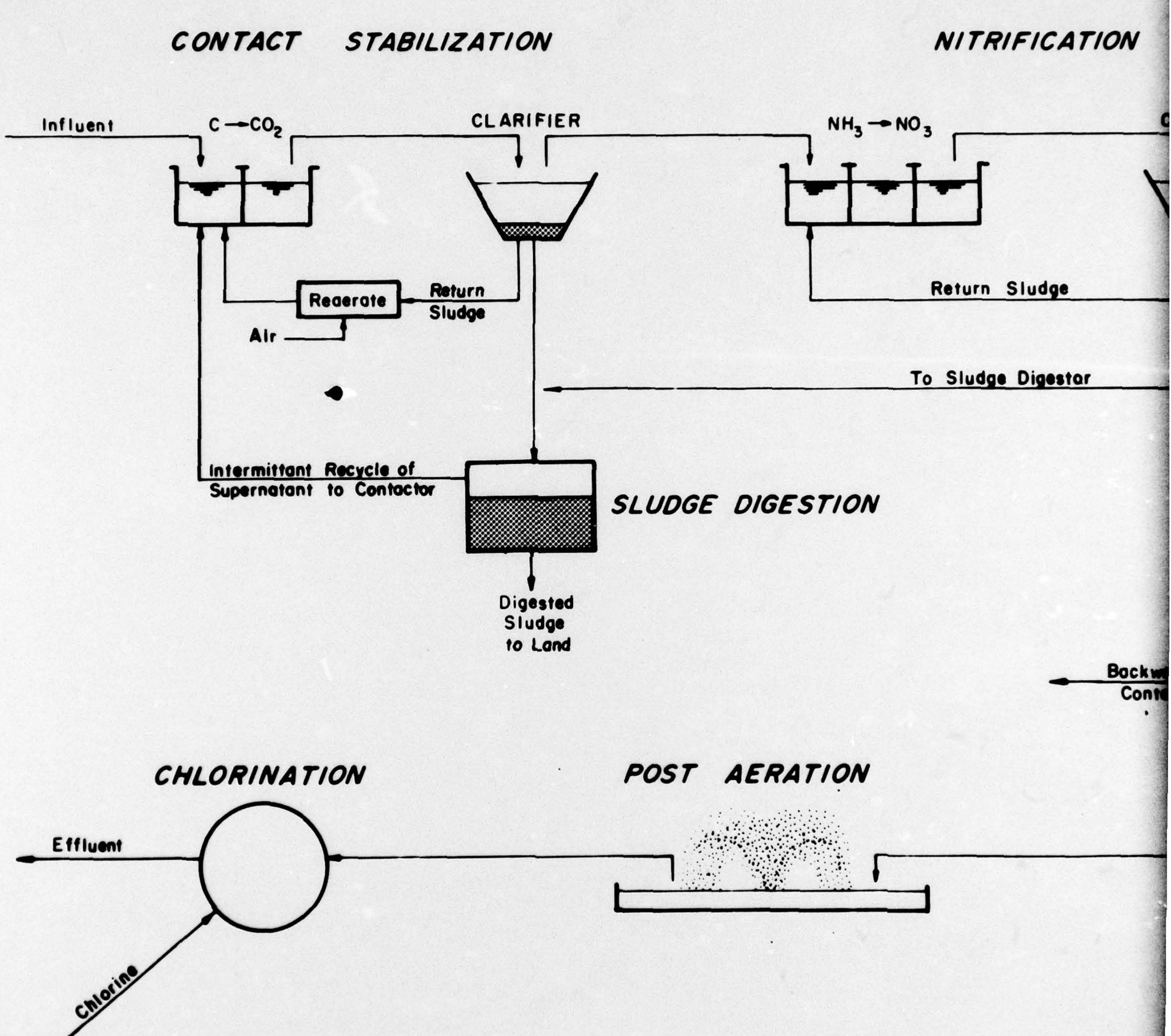
ATER TREATMENT SYSTEM

EXHIBIT III-6

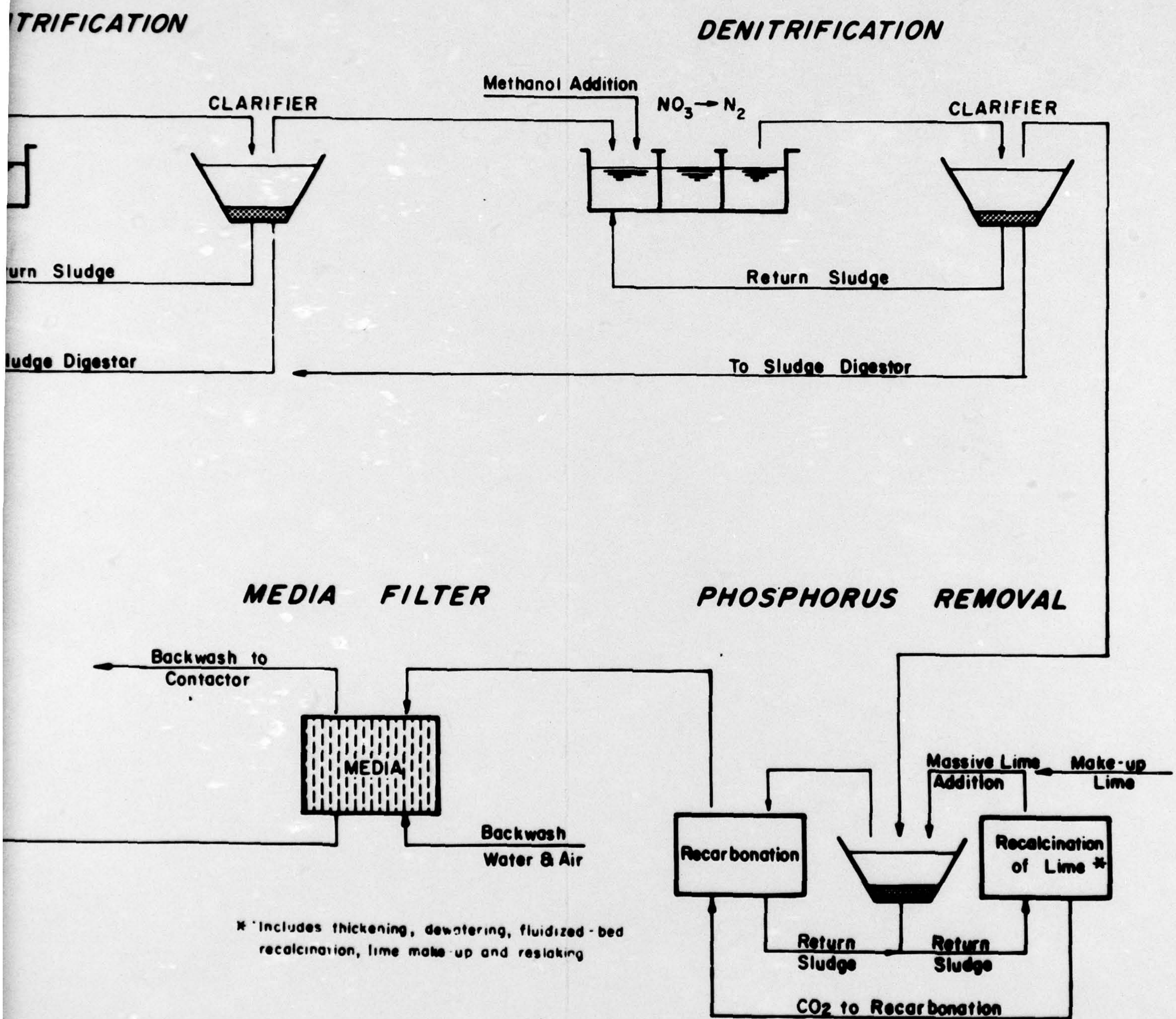


TYPE D WASTEWATER TREA



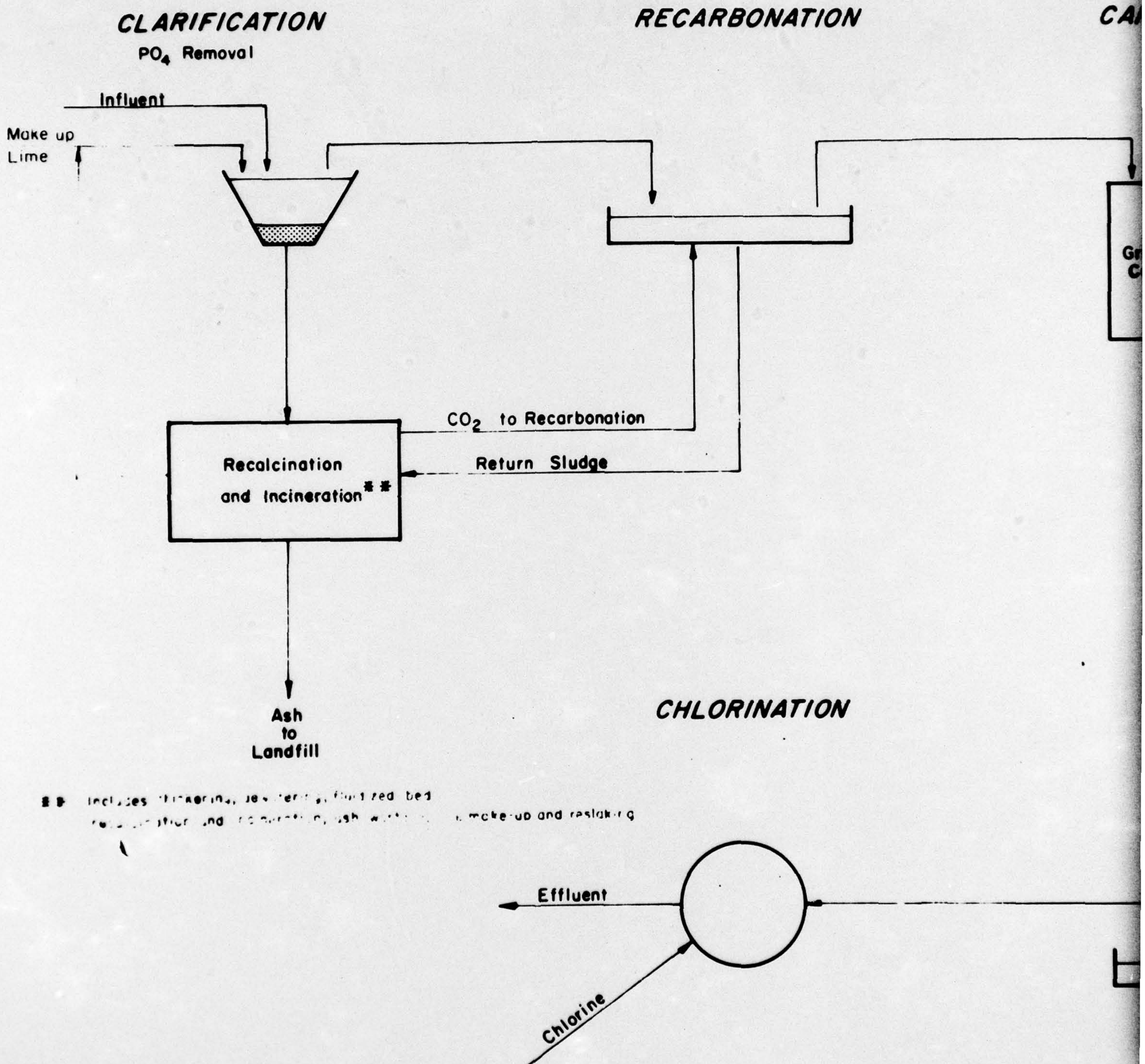
WATER TREATMENT SYSTEM

EXHIBIT III-7



* Includes thickening, dewatering, fluidized-bed recalcination, lime make-up and reslaking

TYPE E WASTEWATER TREATM
(PHYSICAL - CHEMICAL TRE



** Includes [illegible] bed [illegible] make-up and reslaking

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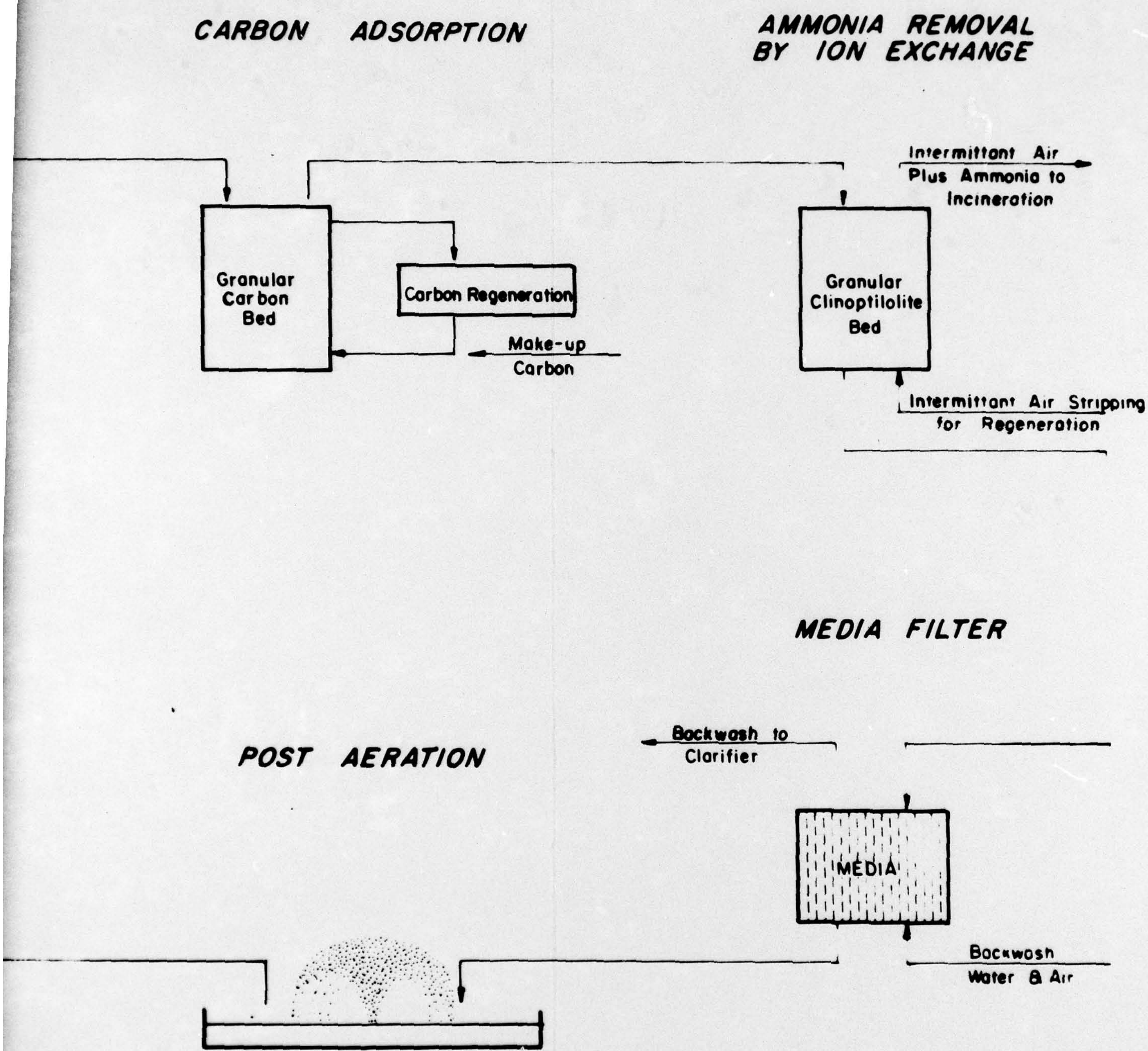
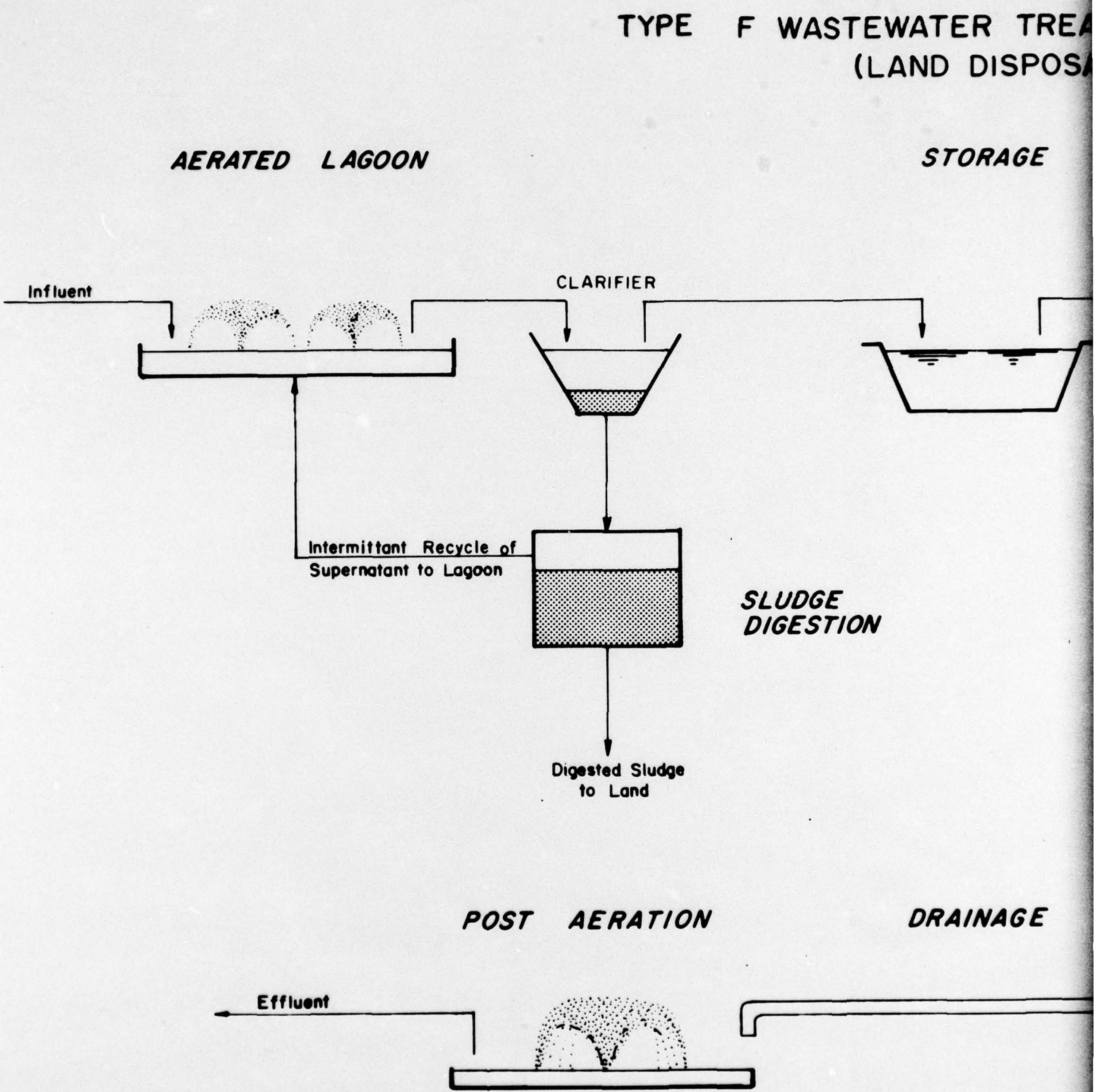
TER TREATMENT SYSTEM
HEMICAL TREATMENT)

EXHIBIT III-8

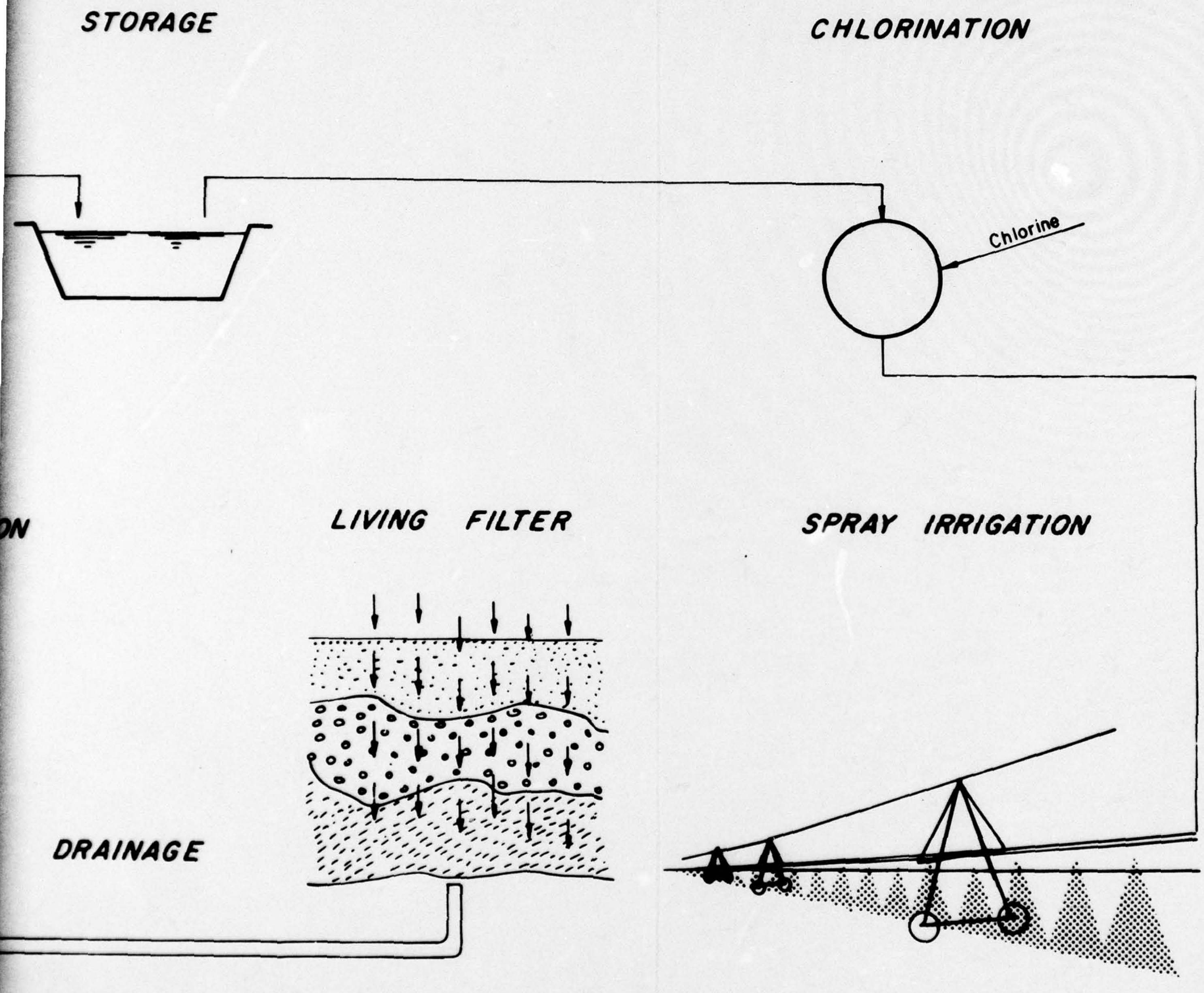



TYPE F WASTEWATER TREA
(LAND DISPOS
AERATED LAGOON
STORAGE
Influent
CLARIFIER
Intermittant Recycle of
Supernatant to Lagoon
SLUDGE
DIGESTION
Digested Sludge
to Land
POST AERATION
DRAINAGE
Effluent

2

TEWATER TREATMENT SYSTEM (LAND DISPOSAL)

EXHIBIT III-9



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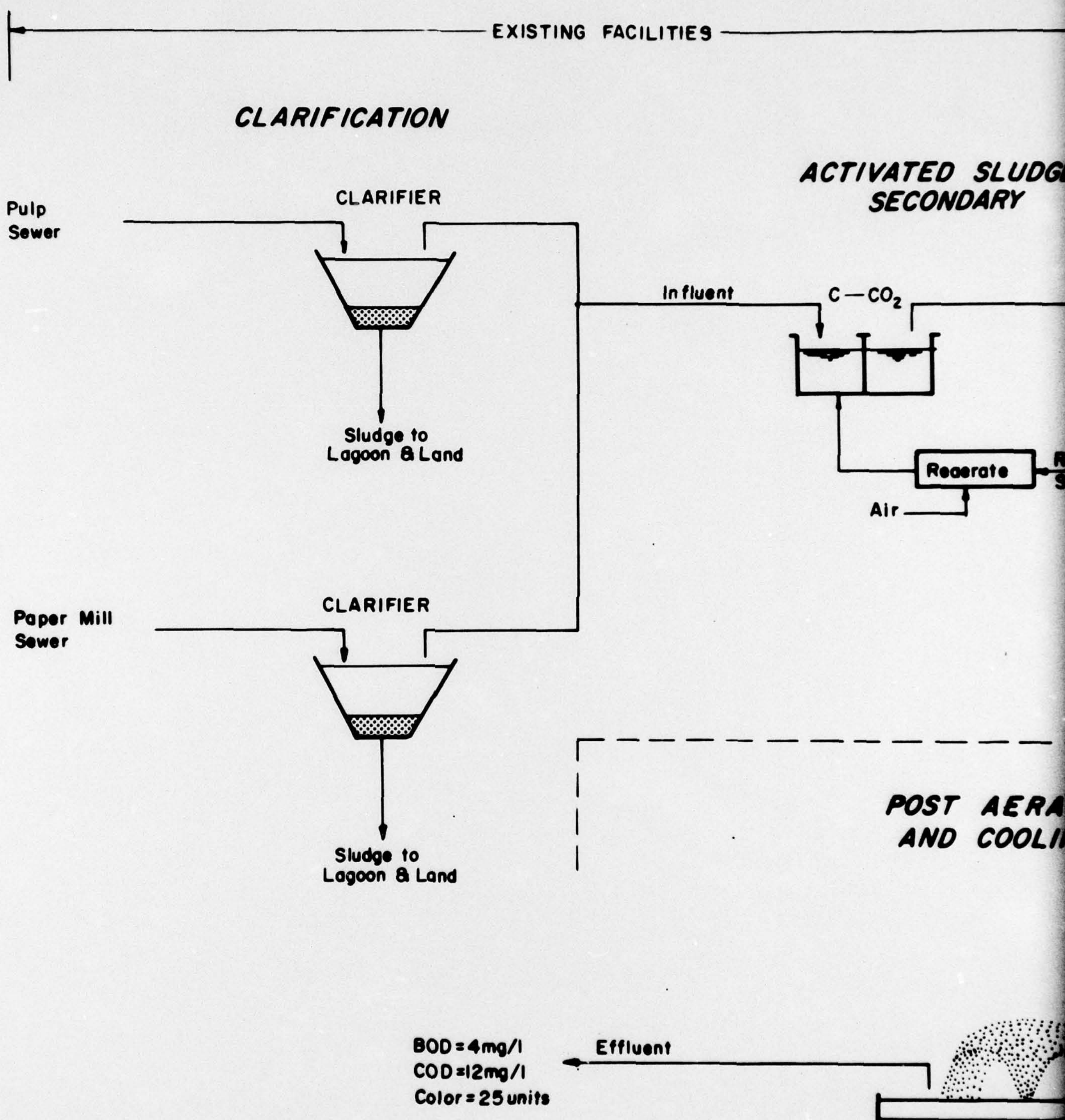
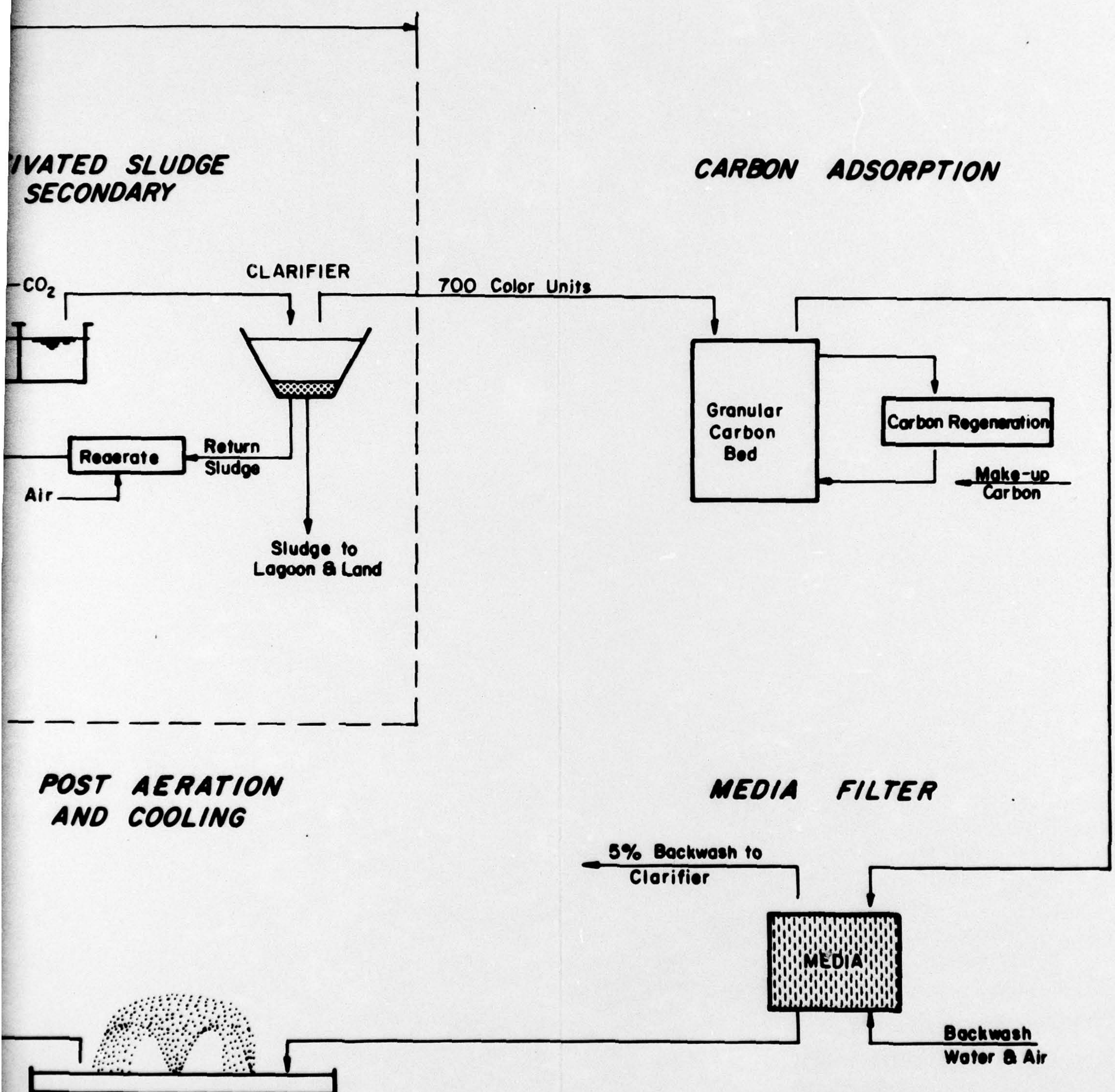
P. H. GLATFELTE
TREATMENT ALTER



GLATFELTER CO.
NT ALTERNATIVE A

EXHIBIT III-10



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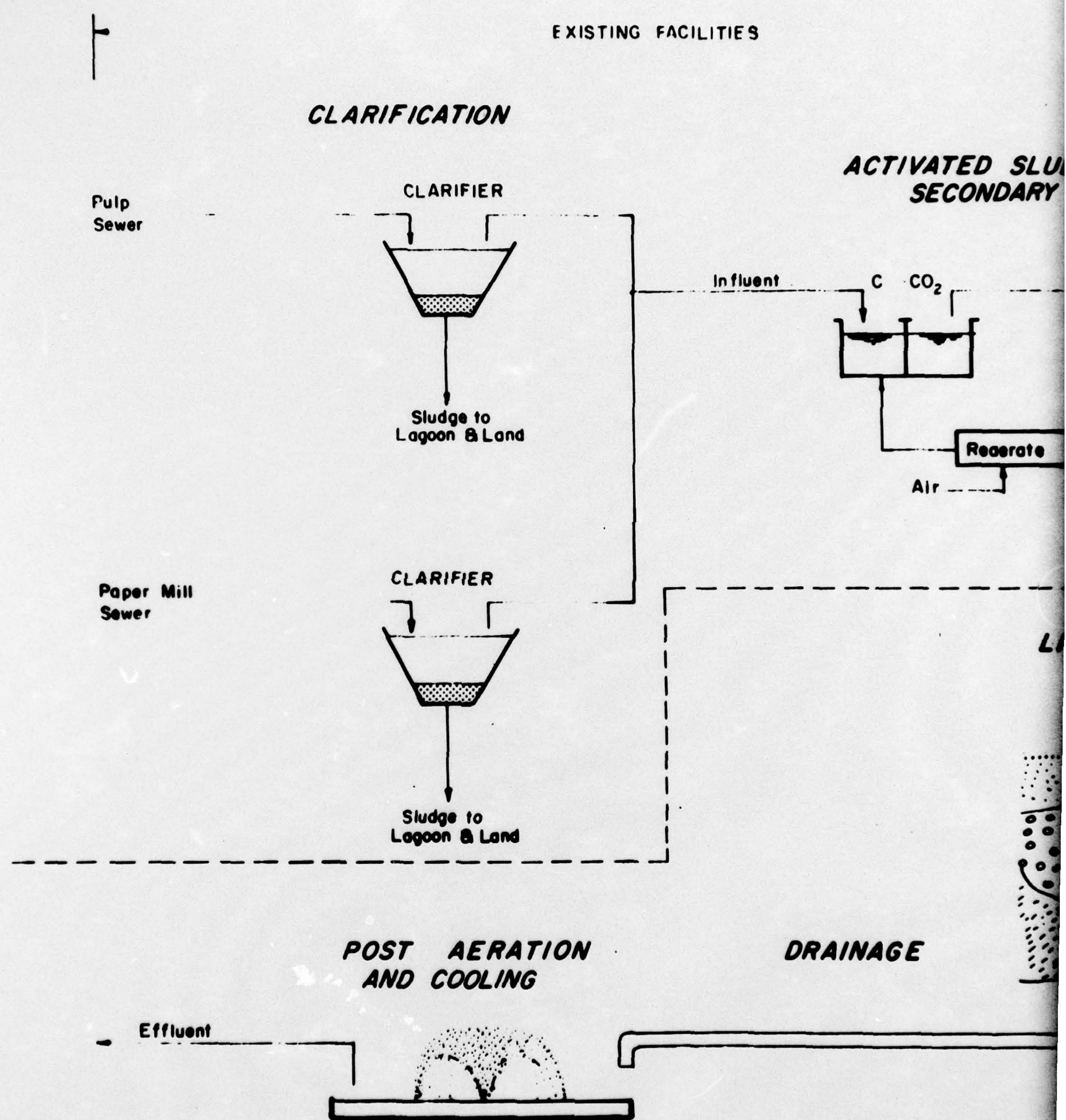
TREATMENT ALTE



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. GLATFELTER CO.
MENT ALTERNATIVE B

EXHIBIT III-11